WEST AFRICAN CACAO RESEARCH INSTITUTE

ANNUAL REPORT

April, 1945, to March, 1946

TAFO, GOLD COAST

Published on behalf of the West African Cacao Research Institute by the Crown Agents for the Colonies, 4, Millbank, London, S.W.1.

1947.

Price 5/-

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STAFF LIST.

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Division of Soil Science and Chemistry.	M. Greenwood, M.B.E., M.Sc. C. F. Charter, M.A.
Division of Agronomy and Station.	R. J. Benstead, N.D.A., C.D.A. J. Paine, B.Sc., A.R.C.S., A.I.C.T.A. D. Westwood, B.Sc., A.R.C.S.
Secretary	G. H. Neal, F.R.S.A., F.I.P.A.

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I. POLICY AND ORGANIZATION.

The London Cacao Conference.

On the recommendation of the London Cocoa Research Committee the Secretary of State for the Colonies agreed to a conference being held in London to consider factors relating to the production of cacao and to define and assign lines of future research. The conference was held at the Colonial Office between May 28th and June 1st, 1945 under the Chairmanship of the Duke of Devonshire, K.G., M.B.E. Representatives of technical and scientific bodies and of manufacturing interests attended ; the W.A.C.R.I. delegates were Messrs. O. J. Voelcker, A. F. Posnette and J. Nicol.

Among other matters the conference considered in detail the work and organization of W.A.C.R.I. and made recommendations. These were of such importance to the Institute that no apology is made for summarising them in this annual report. The lines of work recommended were :—

1. The establishment at Tafo of type collections of different varieties of *Theobroma cacao* and of different species of *Theobroma*.
2. The selection and hybridization of cacao.
3. Investigations into the factors which control the economic life of a cacao tree.
4. The determination of soils suitable for cacao production.
5. Investigations into the nutrient requirements of cacao.
6. Investigations into the climatic requirements of cacao.
7. Investigations into establishment and cultivation of cacao.
8. The study, with a view to formulating control measures, of virus diseases (swollen-shoot) and capsid pests (*Sahlbergella, Distantiella*).
9. The recording of other diseases and pests with a view to their control should any become of economic importance.

In order that all these lines of work should receive adequate attention the conference recommended that W.A.C.R.I. should be staffed as follows :—

Director	1
Principal Research Officer	1
Agronomists	3
Chemist (Insecticides and Fungicides)...	1
Entomologists	6
Plant Pathologists	5
Plant Breeders	2
Plant Physiologists	2
Soil Scientists	4
Statistician	1
Secretary	1
Total	27

As was made clear in the first annual report of the Institute, work has been concentrated on swollen-shoot disease and capsid pests ; these have continued to receive the greatest attention during the past year and will continue to do so until such time as the problems associated therewith are solved. The conference, however, made it clear that there was pressing need for research work other than that connected with pests and diseases. Our exact knowledge of the fundamental requirements of cacao in regard to nutrition and environment is fragmentary, and we have yet to devise better methods of growing cacao in West Africa.

The conference afforded a valuable opportunity to the W.A.C.R.I. delegates for discussing the many and varied aspects of cacao research with workers from other parts of the Empire and with the leading authorities in Great Britain.

The prominence given by the conference to the West African Cacao Research Institute afforded ample grounds for supporting the decision, taken in 1944, to place the Institute on a permanent footing.

ADMINISTRATION.

Shortly after the cessation of hostilities in Europe the post of Minister of State resident in West Africa was abolished and his organization gave place to the Office of the West African Council. The Institute is now under the administrative control of that office pending the formation of a Governing Body. The opportunity is taken here of expressing gratitude for the keen interest taken by Viscount Swinton and by his successor, Lord Balfour, in the affairs of the Institute.

The Institute, however, is still awaiting a legal constitution ; in the absence of legislation appointments for the Institute have been made to the Gold Coast Government, whence they are posted or seconded to the Institute. Not unnaturally this causes uncertainty to those concerned and these *ad hoc* arrangements cannot be considered satisfactory. It is hoped that the necessary legislation to make the Institute an independent body will be passed without undue delay. The Gold Coast Government has materially assisted by placing the Institute's pensionable staff in their printed estimates thereby undertaking to guarantee pension rights.

At the first meeting of the West African Council, held in Accra on January 22nd, 1946, at which the Secretary of State for the Colonies presided, proposals for financing the Institute were discussed. At present no decision in this respect has been taken ; thanks are due to the Gold Coast Government for continuing to advance money to the Institute. No doubt adequate arrangements will be made in due course to give the Institute the financial stability necessary for long term research work.

STAFF CHANGES.

During the period under review Mr. J. West joined the staff as Principal Research Officer and acted as Director during the latter's absence on leave. Mr. West had been closely connected with cacao research under the Department of Agriculture in Nigeria for a number of

years, and his knowledge of cacao in that territory has been of great value to the Institute, the scope of which is, of course, West African. The staff has been further strengthened by the arrival of Mr. J. McA. Todd, Pathologist, and Mr. R. G. Donald, Entomologist. The post of Secretary has been filled by Mr. G. H. Neal. Mr. A. F. Posnette was promoted Senior Specialist.

Mr. B. L. Hancock, Botanist, resigned from the Colonial Agricultural service to take up an appointment with a commercial firm in England. Mr. M. Greenwood, M.B.E., Senior Chemist, returned to the Department of Agriculture, Gold Coast, but has continued certain important lines of investigation at Tafo on the mineral requirements of cacao. An account of his work is included in the Department of Agriculture's Annual Report. Formerly Mr. Greenwood was working part-time with the Institute and part-time for the Department, but with the posting of Mr. Charter, Soil Scientist, to the Institute Mr. Greenwood was enabled to return to his substantive post with the Department. Mr. Box, Senior Entomologist, left the service.

The total European staff at the end of March, 1946 was 16—an increase of one over the previous year.

The total African pensionable staff has been increased by two, bringing the total to 36. Where possible, recruitment has been made from ex-service men ; with respect to soil survey and mapping, certain of these have proved themselves excellent. Mr. F. E. Decker, Entomology, and Mr. St. J. J. Nuno, Pathology, were promoted Senior Technical Assistants and Mr. A. A. Addy and Mr. W. Bart-Plange were promoted Senior Clerical and Senior Accounting Assistants respectively.

Organization.

The organization of the Institute has remained substantially the same. The Secretary arrived too late in the year to relieve the Agronomist in charge of the station of the increasing duties connected with clerical and accounting work ; the full benefits of the appointment should be apparent in the future.

The Division of Chemistry and Soil Science has been reorganized both with respect to the change of precedence accorded to certain lines of work and to concomitant alterations in the laboratory. With the limited staff available it was decided to press forward with the cacao soil survey and to postpone major investigations on soil fertility until more were known about the soils on which cacao is being grown.

The Institute's Entomological sub-station at Owena, Nigeria, has been under the immediate charge of Mr. F. E. Decker, Senior Technical Assistant, during the latter part of the period under review.

Steps are being taken to appoint in a temporary capacity, a Civil Engineer to plan and supervise the construction of permanent buildings and a pipe-borne water supply.

Co-operation with Departments of Agriculture.

Close co-operation exists between the Institute and the Gold Coast and Nigerian Departments of Agriculture.

In the Gold Coast, Departmental discussions concerning cacao production or disease control have been attended by certain of the Institute's staff, and important meetings of the Institute have been attended by Departmental staff. By this means the knowledge of both is pooled and common agreement reached. Following on these discussions, field experiments are being laid down at Konongo, the Soil Scientist of the Institute assisting in the choice of land and experimental layout while the Department supplies the supervision and maintenance.

The propaganda film on the control of swollen-shoot disease was filmed at Tafo by the Public Relations Department and is to be issued by the Gold Coast Government. Certain of the Institute's staff spent much time in helping the Public Relations Officer to ensure that the film would be both technically correct and good propaganda.

Officers of the Agricultural Department have assisted the Institute not only by the collection of mealybugs for identification and of material showing atypical symptoms of swollen-shoot, but also in supplying the benefit of their local knowledge to officers of the Institute when on tour.

The visits of parties of Chiefs and farmers to the devastated areas of the Eastern Province and to Tafo have continued. An Agronomist of the Institute and the Chief Agricultural Officer, Eastern Province, co-operate in impressing on these visitors the destruction which will occur if control measures are not put into practice, the actual method of control and the potentialities of replanting. These examples by no means include all the joint activities of the Institute and the Department of Agriculture.

In Nigeria, the Institute has been able to assist the first efforts of the Department and Government in putting into effect control measures against the spread of swollen-shoot. An Agronomist with considerable experience of this work visited Nigeria to advise on the actual procedure of cutting out.

The Principal Research Officer collaborated with the Agricultural and Forest Departments in devising experiments to ascertain whether cacao could be grown successfully in certain parts of Nigeria without the wholesale destruction of forest which is unfortunately the current native practice. In Gold Coast areas of comparable climate and soil a canopy of tall forest trees is left to supply shade for the cacao.

The Department has accorded great help to visiting officers of the Institute. The cacao experiments at Ibadan, Ina and Owena, the native method of growing cacao and the peculiarities in the distribution of capsid pests make these visits most desirable. Equally, officers of the Department have been able to get a clearer picture of swollen-shoot disease from their visits to Tafo.

It is regretted that surface and air mails between Ibadan, Nigeria, and Tafo, Gold Coast, take many days, and it is hoped that not only will the mail services improve but that direct telephone or radio communication will be installed.

The Sierra Leone Government, through its Agricultural Department, has rendered every assistance during two visits made by one of the Institute's Entomologists in a search for parasites of Capsids.

Co-operation with French West African Colonies.

Visits to Tafo by French Scientists have been greatly appreciated by the Institute—in particular that of M. Blondeleau, Inspector General of Agriculture, Ivory Coast. Unfortunately shortage of the Institute's staff precluded the examination of cacao in the Ivory Coast, French Cameroons or French Equatorial Africa though a rapid visit through French Togo was undertaken by the Soil Scientist with a view to determining what soils occurred in the cacao areas of that territory.

Cacao Research and Survey Advisory Committee.

The fourth meeting of the Committee was held at Tafo and Accra on February 19th and 29th, 1946, respectively. No other Advisory Committee meetings were held during the period under review.

The Nigerian delegates included the Deputy Director of Agriculture and the Chief Conservator of Forests, but the absence of a representative of the Political Administration or of the Nigerian Producers was keenly felt. Unfortunately the Gold Coast Producers representative was also unable to attend.

It is with regret that Mr. R. E. Dyer's resignation on grounds of ill health has had to be accepted ; as Nigerian representative of Cocoa Manufacturers he had taken a great interest in the work and progress of the Institute.

The first day of the meeting the Committee stressed the need for early recruitment of Survey Officers to enable the programme of cutting out swollen-shoot diseased trees to be pushed ahead. Consideration was given to the progress reports on the Nigerian and Gold Coast Cacao Surveys, and matters affecting the work and staffing of the Institute were discussed.

The second day of the meeting the Committee, under the Chairmanship of Sir Gerald Creasy, K.C.M.G., O.B.E., Chief Secretary to the West African Council, dealt in detail with the estimates of the Institute and those of the Nigerian Survey. In regard to the European establishment of the Institute the Committee agreed that the estimates for 1946/47 should be based on a staff of twenty—this number having been previously approved by the Secretary of State—and not on a staff of 27 as recommended by the London Cocoa Conference. A cogent reason for not adopting the recommendation for the larger staff for the coming year was the prospect of inadequate housing, laboratory and office accommodation. The Committee agreed to the inclusion of the temporary post of Civil Engineer in the estimates.

Cacao Surveys.

The Gold Coast has now completed the rapid reconnaissance Survey and is proceeding with the detailed farm to farm survey as staff becomes available. The rapid survey disclosed new areas of swollen-shoot diseases, but still more are being found as the farm to farm survey progresses.

In Nigeria, the Department of Agriculture has embarked on a farm to farm survey. Approximately one-third of the cacao areas have now been surveyed. Two main regions of swollen-shoot have been found to occur, one around Olanla the other between Badeku and Akanran. Both these outbreaks are in Oyo Province. However, the total acreage of diseased trees in the areas already surveyed is computed at only 300 acres.

Buildings.

Mention has been made of the intention to recruit a Civil Engineer for carrying out the Institute's building programme. The total cost of construction is estimated at some £80,000 which includes provision for European bungalows, African Staff quarters and labour lines, offices and library; water storage, treatment, and pipe laying.

The delay in undertaking these works has been made inevitable by the shortage of building material. Further delays appear likely since it is considered better to wait until adequate and appropriate supplies are on hand than to attempt construction of permanent buildings with makeshift material.

The temporary European bungalows, built in 1944 to last for three years, are likely to last a little longer without serious deterioration.

Health.

It is most gratifying to be able to report a marked improvement in the general health of the staff. In the twelve months there have only been two hospital cases among the Europeans on the station. For the previous twelve months there were eight. Apart from hospitalization, the number of days lost through minor attacks of malaria and other illness has also been considerably reduced. This improvement reflects credit on the energetic action taken by the Entomologist and Agronomist in charge of the station in carrying out anti-malarial control.

Through the co-operation of the Medical Department the Institute now has a dispensary and a resident male nurse. Supervision is given by weekly visits of the Senior Medical Officer, Koforidua, to whom the Institute is greatly indebted.

Annual Report.

It will, of course, be appreciated that the Annual Report embodies the reports of the research staff (much of it word for word); to them, both Senior and Junior, is due the credit for the progress recorded in the subsequent sections.

ACKNOWLEDGMENTS.

The Director wishes to place on record the Institute's appreciation of the interest and encouragement given by scientists and technical departments in Great Britain and in West Africa. Particularly helpful has been the assistance accorded to the Institute by the Gold Coast Government.

II. VIRUS RESEARCH.

1. STRAINS.

The virus diseases of cacao in West Africa show considerable variation in the expression of their symptoms in the field. In many discrete outbreaks and sometimes over wide districts, the effect of the indigenous virus is very mild in comparison with what is known as Strain A. That this is not a result of environmental conditions is evident from the fact that a faithful reproduction of symptoms can be induced on graft-infected seedlings at Tafo.

The number of virus strains under observation has increased during the year as a result of the discovery of isolated outbreaks by the Cacao Surveys. The tendency for isolated outbreaks to contain new virus strains is very marked. Now that the Cacao Reconnaissance Survey has been completed it is hoped that few new strains remain to be discovered.

Distribution.

Mild strains have a wide geographical range and are known from the Ivory Coast, the Western and Eastern Provinces of the Gold Coast, Ashanti and Togoland and are typical of Nigeria. The acreage involved with virulent strains is considerable, but on present knowledge, they are concentrated in the Eastern Province of the Gold Coast, with scattered outbreaks in Ashanti, the Western Province of the Gold Coast and the Ivory Coast.

Symptoms.

The most striking feature of the outbreaks of mild virus which have been visited is the dearth of dead and moribund trees. In many cases the general condition of the trees gives no indication of the presence of virus disease, and in others only a slight deterioration in the canopy is discernible. Leaf symptoms are usually mild mosaic, flecking, fine vein-clearing and "fern" patterns, while the severe chlorosis and crinkling so typical of virulent cacao viruses are rare. Most of the leaves remain symptomless, but swellings are usually prominent. Two of the new strains are very different from each other and from any of the previously known Gold Coast viruses. One of these was discovered at Mampong on the Akwapim ridge, the other from Western Ashanti. The Mampong strain is the most invasive yet studied, symptoms appearing on seedlings about three weeks after budding. The acute symptom, in the form of yellow vein-banding sometimes merging into complete "yellows", is most pronounced on the leaves developing immediately above the infecting graft, and least on those on the opposite side of the

stem. This symptom is usually restricted to one flush of leaves, subsequent flushes appearing healthy except for slight general chlorosis. Large swellings develop later.

The Ashanti strain takes about three months to produce symptoms on graft-infected seedlings. This strain produces broad, completely clear, yellow bands along the primary veins sometimes with severe crinkling and tearing as the leaf hardens. The leaves appear darker green than normal and there is no indication of any diminution in leaf size. This strain resembles that in the Yakasse district of the Ivory Coast more closely than other Gold Coast viruses.

There is evidence from the first series of insect transmissions that Strain A (New Juaben) may be a complex of at least two strains. Besides transmitting the complex, *Ferrisia virgata* Ckll. infected some seedlings with a strain closely resembling Strain B (Bisa) which causes large swellings and only transient leaf symptoms. *Pseudococcus njalensis*, Laing, transmitted a strain which caused mosaic but so far no swellings.

Results obtained with the coppicing trial and with resistant selections throw doubt on the stability of the virulent Strain A. If this suspected instability is a fact, it indicates either a complex nature for Strain A or ease of attenuation. In either case, a knowledge of the relationship of mild strains to the virulent becomes a necessary basis for future work. The relative distributions of mild and virulent strains are sympathetic to a theory that the latter have emerged (either by synthesis or mutation) from the former. Both in the Gold Coast and in Nigeria it is probable that certain of the outbreaks of mild virus have a prolonged history. Should this theory be proven correct, it will be almost as important to eliminate mild strains as virulent ones, since the latter may develop from the former.

2. Effect of Virus on Yield.

Immunization Experiment at Tafo.

In the three-acre Immunization Experiment started in 1942, two mild viruses are compared with the virulent Strain A and with healthy trees. Table Table 1 shows the effect of the three strains on the number of pods per tree after one and three years infection.

TABLE 1.

MEAN YIELD PER TREE (IN PODS).

Treatment—1942.	1943–4.	1945–6.
Uninfected	17·4	15·2
Bisa Strain B	17·5	18·0
Kpeve Strain C	15·3	8·3
New Juaben Strain A ...	11·2	0·2

A difference of 5 pods per tree is statistically significant.

Despite the death of infected cacao on adjacent plots with consequent breaks in the cacao canopy, the uninfected trees have not suffered in any significant reduction in yield. The trees infected with Strain B (Bisa) have also maintained their yield. On the contrary, the Kpeve (C) virus has caused a reduction of nearly 50 per cent. in number of pods and also a significant reduction in weight of wet beans per pod.

The virulent Strain A (New Juaben) reduced yield in the first crop after infection and there was practically no yield this season from the few surviving trees.

On the $8\frac{1}{4}$ acres at Tafo described under Rate of Spread, the effect of Strain A on yield is recorded in Table 2.

TABLE 2.

Percentage infected trees.	Number plots concerned.	Mean number trees per plot.	Percentage infected bearing trees.	Percentage dead trees.	Mean number of pods per plot.
0	2	146	—	—	1,255
1– 20	8	163	4·8	1·5	1,405
20– 40	10	143	24·1	1·3	1,229
40– 60	6	138	45·1	5·1	1,021
60– 80	5	138	47·0	24·5	731
80–100	2	158	57·0	35·8	428

3. Rate of Spread.

Previous work on rate of spread of swollen-shoot has been confined to the study of radial spread only and the results obtained underestimated the rate of destruction of farms by uncontrolled swollen-shoot. A demonstration has been started to indicate the rate of deterioration and destruction wrought by the virulent Strain A on mature trees over a fairly large area. Readings are made on the general increase in the proportion of diseased trees, and annual yield records give the decline in yield.

The site, $8\frac{1}{4}$ acres divided into $\frac{1}{4}$-acre blocks for ease of recording, is covered by cacao typical of the Tafo district.

In August, 1945, when the first readings were taken, about one-third of the trees were noticeably infected. There were thirty discrete outbreaks ranging in size from single isolated infected trees to one covering more than half an acre, and in addition seven outbreaks only partly within the demonstration plot.

By March, 1946, the number of healthy trees in the area had been reduced by 10 per cent. The exact increase in the zone of infection of each outbreak has not yet been worked out, but Table 3 gives the revised distribution of $\frac{1}{4}$-acre plots arranged according to the percentage number of infected trees in each.

TABLE 3.

Percentage of infected trees.	Number of plots concerned.	
	August 1945.	March, 1946.
0	2	0
1– 20	8	10
20– 40	10	7
40– 60	6	7
60– 80	5	7
80–100	2	2

Rate of spread of Strain A has also been recorded on two areas near Osino in the Eastern Province of the Gold Coast. At Domi, approximately 120 trees were diseased in 1941. Four years later the disease had spread over an area of some 10 acres. At Nsutam, an outbreak covering 0·05 acre in 1941 has increased to 3·5 acres in less than five years.

In July, 1942, an observation plot was started on the Unit Farm run by the Department of Agriculture at Abetima, near Dawa, Krobo. The virus Strain H is of intermediate virulence, being a less rapid killer than Strain A. Table 4 shows the rate of radial spread of the outbreak, but does not take into account the formation of other outbreaks in the Unit Farm.

TABLE 4.

RATE OF SPREAD OF DAWA STRAIN.

Year.	No. healthy.	No. infected.		Percentage infected.
		Alive.	Dead.	
1942–3	229	5	0	2·1
1943–4	218	16	0	6·8
1944–5	200	28	6	14·5
1945–6	43	139	52	81·6

4. Seed Transmission.

The mass seed-transmission trials have been continued. Seed was collected from trees infected with Strains A, B and C and also from trees carrying combinations of these strains. The actual numbers planted are shown in Table 5, which includes also the total number of seeds planted during these trials.

TABLE 5.

SEED TRANSMISSION TRIAL DATA.

Strain.	Seeds Planted.			
	During 1945–46.		Total to Date.	
	No. Planted.	Percentage germination.	No. Planted.	Percentage germination.
A	325	89	5,577	80
B	2,749	89	2,813	89
C	715	89	5,042	79
BC	2,984	94	2,984	94
CB	1,351	92	1,351	92
Control			1,088	96

None of these seedlings has shown signs of virus disease and these trials will cease.

The dwarf seedlings which sometimes result from beans taken from rounded infected pods and which were once thought to be infected by seed-transmission of the virus, have been investigated by two methods. Inarching these dwarfs to normal seedlings has failed to transmit swollen-shoot. The dwarf seedlings develop the usual symptoms after infection by grafting with Strain A. It is therefore probable that the dwarfing is a physiological effect due to the infection of the parent tree.

5. Coppicing of Cacao.

The growth of suckers or water-shoots from the base of the tree is characteristic of healthy cacao, and they may later comprise the entire trunk-system in aged trees or in such as have sustained severe damage to the main axis.

Shortly after the discovery of swollen-shoot, but before its virus nature was determined, the Department of Agriculture suggested control by cutting down infected trees. In 1936—37 a certain farmer adopted this suggestion and coppiced his diseased trees. At present, 45 have survived out of about 1,000 and of these survivors 19 show relatively mild leaf symptoms while the remainder are apparently symptomless. Almost all seem capable of bearing well. Cacao has been replanted where coppiced trees failed to regenerate. Mortality amongst the seedlings has not been high, and many of the young trees, though infected, show no appreciable ill-effects.

The regeneration of this farm was so good that it was decided to make further investigations on the effect of coppicing diseased trees.

Methods.

Four circular outbreaks of Strain A were chosen, each comprising 150–250 diseased trees. A perimeter of symptomless trees was included in each case to allow for subsequent observations on latency of infection

and rate of spread ; the perimeters were separated from adjacent cacao by a coppiced ring 20 feet wide. Each tree was then classified as either : 0—apparently healthy ; 1—doubtful ; 2—infected, but without serious effects ; 3—semi-defoliated ; 4—almost completely defoliated ; 5—with living tissue at the base only ; 6—dead. Subsequently, the suckers were classified according to the intensity of leaf symptoms as : *a*—mild ; *b*—intermediate ; *c*—severe.

Each plot was divided into two by an approximate diameter ; one half-plot was retained in each case as a control, and in the other, the trees were coppiced at a height of 18–24 inches from ground-level. Three of the plots were treated in June, 1945, the fourth in August. Readings on the symptom-category of the controls, and on the symptom-category, number of chupons and heights of the chupon-masses are made at quarterly intervals.

Observations to date.

(1) *Regeneration.*

(*a*) *Initial Regeneration.*

Table 6 indicates the incidence of regeneration during the three months following treatment.

TABLE 6.

INCIDENCE OF DEAD TREES AND SLOW REGENERATION 3 MONTHS AFTER TREATMENT.

Initial symptom-category before coppicing.	Plot 1.			Plot 2.			Plot 3.			Plot 4.		
	**	*	†	**	*	†	**	*	†	**	*	†
0. Apparently healthy ...	378	13	5	80	0	26	172	0	14	126	0	4
1. Doubtful ...	6	0	3	12	1	8	3	0	2	5	0	1
2. Slightly affected ...	5	0	1	14	0	11	16	1	4	14	0	1
3. Semi-defoliated ...	14	0	6	44	0	31	40	0	32	33	7	4
4. Severe defoliation	9	4	1	23	0	20	48	11	27	26	15	8
5. Living at base only ...	3	1	2	8	4	3	19	15	4	9	6	1

** Number at time of treatment.
* Number dead after 3 months.
† Number still dormant or showing poor regeneration after 3 months.

The excellent regeneration of healthy material is at once obvious, whereas that of categories 4 and 5 is poor. As far as the ability to regenerate at all is concerned, there appears to be a critical stage in a tree's decline. A tree, almost completely defoliated, or with only the base remaining alive will probably succumb to coppicing, or, at the best produce a very meagre chupon growth ; on the other hand, the chance

of immediate survival of a tree with only half the normal complement of leaves is high, though here again, the growth tends to be poor. Exceptions occur, of course, and a few of the best suckers on the plots have arisen from trees of category 3. Occasional specimens of categories 4 and 5 have been found capable of producing a coppice-growth of surprising vigour.

(*b*) *Subsequent vigour and survival.*

The healthy coppiced trees have continued vigorous growth, in many cases right through a season remarkable for the length of the dry period and the severity of attack by *Distantiella theobroma :* mortality has been almost nil. On the other hand, two-thirds to three-quarters of originally infected trees are now dead, this largely due to failure to survive the dry season. Almost all the infected plants referred to in Table 6 have since died. Destruction of the trees follows a much slower course in the non-coppiced plots.

(*c*) *Mildly infected trees.*

In the four coppiced half-plots, 152 symptom-bearing trees were still alive after the dry season, and of that number, 49 were referable to category " a " (mild). Many plants in this category show vigour comparable to that of the healthy material and their symptom-expression is exceedingly mild ; characteristically, only the occasional leaf shows a mild mottle or partial chlorosis, while the majority of leaves contrast with what one would expect from Strain A, but is reminiscent of the survivors in the farm treated in 1936 and referred to above. Numerous explanations suggest themselves, mainly concerned with possible qualitative or quantitative changes in the virus following the coppicing treatment, and this aspect of the problem is being investigated.

Conclusions to date.

(1) When healthy cacao trees are coppiced, the survival rate is high.

(2) When diseased trees are coppiced, the majority will die comparatively quickly. Too large a proportion will continue a temporary existence for this method of removing diseased trees to constitute an efficient method of control.

(3) Certain of the diseased survivors show a degree of vigour comparable with that of healthy material, this being concomitant with very mild symptoms. It is thought that such trees may survive indefinitely.

6. Resistance to Virus.

Virus resistance work may be considered under three heads, (*a*) the selection of potentially resistant material, (*b*) the symptomatology of resistant material and (*c*) the nature of resistance.

(*a*) *The selection of potentially resistant material.*

During the past five years, more than 500 selections have been made, most of them from healthy or apparently mildly diseased trees growing in devastated farms. The process of testing involves the infection of

budlings with the virulent Strain A, which has eliminated about 50 per cent. of the original collection. Only about 20 of the remaining clones seem worthy of further investigation and six appear to be strikingly resistant. Of the 25 clonal selections made from Trinitario trees growing at Aburi, seven have continued to show conspicuous vigour despite infection for three or four years. Our policy is to discontinue selection, at least temporarily, and concentrate on intensive propagation and testing of promising clones.

(*b*) *The symptomatology of resistant material.*

The establishment of Strain A virus in normal Amelonado scions is followed by reduction of leaf-area in subsequent flushes, crinkling of the leaves and various intense mosaic and chlorotic patterns. Growth is severely checked and this is followed or accompanied by defoliation and dieback. Similar infection of a scion of a resistant clone is followed usually by a growth check and the occurrence of marked symptoms on the first flush ; subsequent growth is satisfactory. Detailed measurements on the resistant clone SS. 167 have shown that its growth-rate is only slightly poorer than that of healthy plants. Leaf symptoms become inconspicuous and may be absent for as long as 18 months. Occasionally a flush will show intense symptoms, but more usually the mosaic pattern is comprised of a scattered flecking or " fern pattern." Swellings may develop but are usually inconspicuous. Repropagation by budding such mildly diseased plants is usually characterised by obvious symptoms on initial growth, followed by a lapse into the indistinct phase.

(*c*) *The nature of resistance.*

A full understanding of this is considered to be of fundamental importance. As with the closely related problem arising from the work on coppiced cacao several explanations are feasible. It is already known that the selection SS. 167 is infected with a mild virus which may be an attenuated form of Strain A, against which this clone is apparently " immunised".

7. Alternative Host Plants of Swollen-Shoot.

Pending the perfection of a technique for insect transmission, work on possible alternative host-plants has been continued along ecological lines.

A forest tree survey is in progress on the recently-acquired Square Mile. Every tree (except cacao) above the sapling stage is being spot-planned and classified into one of three age/height categories. In addition to providing data for correlation with the soil survey of the same area, it is hoped that it will provide fundamental information on the statistical composition of the forest tree population of cacao farms in the Eastern Province.

8. Control of Swollen-Shoot.

The Old Station, Tafo.

It is too early to expect any decrease in outbreaks of swollen-shoot

on the original 60 acres as a result of cutting out infected trees on the new acquisition, and new outbreaks have occurred at the same rate as during the past four years (Table 7). Now that it has been proved that young nymphs (1st and 2nd instars) of *Pseudococcus njalensis* can transmit the virus and are carried by wind, the " scatter " type of spread of swollen-shoot apparently at random and over considerable distance can be attributed to the wind dispersal of infective insects.

The control of " radial " spread of outbreaks has been maintained during the year. Assuming that the spread of an outbreak is stopped if there is no infection for six months, 17 outbreaks have been completely controlled in the year between September, 1944 and September, 1945, while 30 may be still active. During this period only definitely infected trees have been removed, which has lessened the efficiency of the control measures compared with previous years when symptomless contact trees were also removed. Consequently the total number of infected trees removed has increased, and Table 7 shows that this is chiefly due to those removed from old outbreaks (*i.e.*, at second and subsequent treatments).

TABLE 7.

STATION OUTBREAKS OF SWOLLEN-SHOOT.

Month.	Trees destroyed.			Total.
	New Outbreaks.	New Outbreaks.	Old Outbreaks.	
April, 1945	8	11	18	29
May	2	2	16	18
June	7	11	15	26
July	3	4	19	23
August	1	1	8	9
September	4	4	7	11
October	—	—	10	10
November	—	—	8	8
December	2	2	21	23
January, 1946	6	9	13	22
February	6	11	9	20
March	1	1	16	17
Total 1945–6	40	56	160	216
„ 1944–5	47	53	117	170
„ 1943–4	44	62	74	136

The New Square Mile Acquisition.

Cutting-out treatment started in November, 1945 and by the end of March, 1946, 340 acres had been surveyed and treated.

Table 8 gives the relevant information concerning the 340 acres, but there remain a further 300 acres to be treated.

TABLE 8.

	acres.
Area examined	340
Area of swollen-shoot cut out	71
Number of cacao trees cut out ...	57,512
Area of cacao remaining	206
Area not under cacao	63
Percentage of diseased to healthy cacao	25·5%

Koransang.

This farm, which is one of the Institute's experimental substations, contained mature cacao much of which was infected with swollen-shoot in 1944. The farm is situated in an area devastated by the disease. Cutting out diseased trees commenced in September, 1944 and to date a total of 3,716 have been removed leaving 2,868 mature healthy trees. Table 9 shows that reinfection is continuously taking place.

TABLE 9.

DISEASED TREES CUT OUT—KORANSANG.

1944	Sept.—Dec. 2,603											
	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
1945	161	23	31	245	52	78	64	35	37	143	61	37
	Jan.	Feb.	Mar.									
1946	77	48	21									

The yield has dropped from 25 cwt. in 1944–45 to 17¼ cwt. in 1945–46.

9. Replanted Cacao.

It is most encouraging to report that where cacao has been replanted subsequent to the removal of swollen-shoot diseased trees infection has been on a very small scale.

On the old station at Tafo, gaps caused by the removal of diseased trees have been replanted with cacao. Swollen-shoot has not been observed in any of these young plants.

At Akwadum, planted in 1942, out of some 30,000 young plants one succumbed to swollen-shoot in 1944, two in 1945 and two in 1946 up to April.

At Koransang, planted in 1945, three seedlings became infected out of some 15,000.

At Kukua, 30 acres, Nankese 18 acres and Adunkwanta 26 acres—a total of 74 acres planted in 1945, no disease has been recorded up to April, 1946.

In all these areas particular attention has been paid to the complete destruction of old diseased trees. Where the diseased trees are not removed prior to replanting, swollen-shoot has been found to occur to a considerable extent on the young trees. Nine farms replanted three to six years ago were surveyed south of Koforidua, and in these a number of old diseased trees had been left. Sample surveys showed that the percentage of young trees infected with swollen-shoot varied between 5 per cent. and 38 per cent.

10. Insect Transmission of Swollen-Shoot.

Six series of vector experiments have been set up in the last year and a brief summary of the results at present available is given below :—

Series I.

Insects.

Toxoptera coffeae, Nietner *Mesohomotoma tessmanni*, Aulm.	With virus Strains A, B, C, D and F.
Pseudococcus njalensis, Laing *Ferrisia virgata*, Ckll.	With virus Strains A, C and F.

Technique.

Receptor plants " bombarded " repeatedly with the insects that had fed on the appropriate source plants for varying time periods.

Results.

Aphids (*T. coffeae*) and Psyllids (*M. tessmanni*) did not transmit any of the virus strains tested.

The Mealybugs *Ps. njalensis* and *F. virgata* are both capable of transmitting Strain A, but not, as far as can be judged, Strains C and F.

Transmissions with Strain A.

Ps. njalensis=4 out of 20 plants.
F. virgata =9 out of 20 plants.

Series II.

Vector ; Ps. njalensis.
Virus ; Strain A.

Technique.

Vectors fed for varying periods on various parts of the source plants (*i.e.*, on leaves, on green shoot tissues, and on the hardened bark). Three stages of insects used : adults, 3rd instar nymphs, and 1st and 2nd instar " crawlers."

Results.

(1) All of the stages of the insects tested can transmit the virus to a healthy plant.

(2) Vectors feeding for less than four hours on an infected plant take up enough virus to transmit the disease.

(3) Vectors can become infective after feeding on either leaves, shoot or bark.

(4) The highest percentage of transmissions recorded (80 per cent.) occurred when adults were fed on flush leaves of source plants for 48 hours.

Table 10 gives the numbers of transmissions obtained in relation to the numbers of receptor plants in each group on which establishment of vectors was satisfactory, *i.e.*, feeding for at least 48 hours.

TABLE 10.

Feeding position on "source" plants.	Time period on "source" Plants.			
	4 hours.	8 hours.	24 hours.	48 hours.
ADULTS.				
Leaves ...	0/4	0/3	2/5	4/5
Shoot ...	0/5	0/4	0/5	0/3
Bark ...	1/5	0/4	0/4	0/4
NYMPHS.				
Leaves ...	0/1	1/4	0/4	1/2
Shoot ...	1/4	1/2	0/5	0/3
Bark ...	0/2	0/1	0/1	0/4
CRAWLERS.				
Leaves ...	0/5	0/0	3/5	0/4
Shoot ...	0/0	0/0	0/0	1/2

SERIES III.

Vector ; Ps. njalensis.

Virus ; Strain A.

Technique.

Vectors fed on the flush leaves of source plants for 48 hours, and transferred to healthy plants in varying stages of flush.

Results.

(1) It appears that plants infested with vectors four or five days after the flush leaves have hardened will develop virus symptoms with the greatest speed. This method gave the fastest transmission, which developed symptoms in 17 days, the shortest incubation period recorded for Strain A.

SERIES IV.

Vector ; Ps. njalensis.

Virus ; Strain D ("Nkawkaw").

Technique.

Vectors taken from a natural infestation on a graft-infected tree. The mealybugs were transferred to each of 20 receptor plants.

Results.

Strain D is transmissible by *Ps. njalensis* (7 out of 20).

Series V.

Vector ; Ps. njalensis.
Virus ; Strain A.

Technique.

Source plants infested with vectors that are allowed to feed on the flush leaves for 48 hours. Vectors then transferred to a first batch of receptor plants, and allowed to feed for varying time-periods before being transferred to a second series of receptor plants.

Results.

Sufficient time has not elapsed for any results to have appeared at the time of writing.

Series VI.

Vector ; Ps. njalensis.
Virus ; Strain A.

Technique.

Vectors fed for 48 hours on the flush leaves of the source plants ; then transferred to young cacao seedlings, two to five weeks old, and still carrying their cotyledons.

Results.

Young cacao seedlings can be infected with Strain A by insects and show typical leaf symptoms.

11. Biology of Coccoidea attacking Cacao.

Considerable attention has been given to the biology of Coccoidea associated with cacao, particularly to those at present known to be vectors of cacao viruses.

Pseudococcus njalensis, Laing.

(*a*) *Morphology.* The morphology of the larval instars and the male is now known. W. J. Hall has published a paper on the Taxonomy of this species (" The Identity of a mealybug vector of ' swollen-shoot' virus disease of Cacao in West Africa." Bull. Ent. Res. 36 (3) pp. 305–313.

(*b*) *Ecology.* The life history is now known :—

(1)	*Egg Stage*	A few hours—usually less than 12.
(2)	1*st Instar*	4–6 days.
(3)	2*nd Instar*	10–14 days.
(4)	3*rd Instar*	10–14 days.
(5)	*Adults*	14–30 days.

The average period " from birth to egg laying " is 41 days.

Four means of dispersal in the field are now known with certainty :—

(i) *By Wind.* The first and second instar " crawlers " are carried about by air currents. (This fact, in conjunction with the knowledge that " crawlers " can transmit the virus, goes far to account for certain aspects of the spread of the disease in the field.)

(ii) *By Ants.* If disturbed, ants will carry members of mealybug colonies they are attending, and deposit them either on the same tree, or on to different trees noted in the field on two occasions.

(iii) *By their own volition*—to various parts of the host plant ; adults have been found occasionally walking over the ground. (Whether such insects survive the hazardous journey over the soil, and establish themselves on neighbouring trees is not known.)

(iv) *By human agency. i.e.*, The carrying of infested cacao pods and seedlings from one area to another in order to start up a new cacao farm or replant an old one.

Ps. njalensis has now been taken in the field from some 60 indigenous and introduced food plants apart from cacao.

This species is attended in the field by some 34 species of ants, 27 belonging to the genus *Crematogaster*, six to the genus *Pheicole*, and one to the genus *Camponotus.*

Three internal parasits (one Dipterous and two Hymenopterous), have been bred out from *Ps. njalensis.* One species of Coccinellid beetle is actively predaceous on nymphs and adults during the larval stage.

Ferrisia virgata, Ckll.

Ecology. Observations on this species have been restricted to distribution and alternative food plant records. It is by no means common in peasant cacao farms and is probably of secondary importance as a natural vector of virus Strain A.

Pseudococcus citri, Risso.

Ecology. Observations on this species have been restricted to date on distribution, alternative host plants and ant attendants. One species of parasite—the same species of Cecidomyid that attacks *Ps. njalensis*, has been bred out.

Other Cacao mealybugs.

The following coccids have been taken from time to time on cacao, and will be tried as vectors in due course.

(*A*) *Coccidae.*

(1) *Stictococcus sjostedti*, Ckll.

(2) *Stictococcus gowdei*, Newst.

(3) *Stictococcus multispinosus*, Newst.

(*B*) *Lecaniidae.*

(4) *Ceroplastes sp. H.* 5480.

(*C*) *Pseudococcidae.*

(5) *Pseudococcus concavocerarii*, James.
(6) *Pseudococcus hargreavsi*, Laing.
(7) *Pseudococcus nr. bukobensis*, Laing.
(8) *Paraputo nr. multispinosa*, James.
(9) *Paraputo nr. ritchei*, Laing.
(10) *?Nr. Paraputo H.* 5613.
(11) *Phenacoccus nr. hirsutus*, Green.
(12) *Phenacoccus sp. H.* 5010.
(13) *Lachnodius sp. H.* 5292.
(14) *Geococcus coffeae*, Green.
(15) *Rhizoecus sp. H.* 5288.

(*D*) *Ortheziidae.*

(16) *Newsteadia sp. H.* 5284.

(*E*) *Monophlebidae.*

(17) *Icerya nigroareolata*, Newst.
(18) *Steatococcus sp. H.* 5047.

III. CAPSID RESEARCH.

New light has been thrown on the capsid problem by further work on the fungus *Calonectria rigidiuscula*, (Berk. et Brme.) Sac. This fungus has been proved to cause much of the damage formerly ascribed entirely to *Sahlbergella singularis*, Hagl. or to *Distantiella theobroma*, Dist.

Nature of Capsid Damage alone and Associated with C. Rigidiuscula.

On soft green stems the lesions made by *Sahlbergella* or *Distantiella* are sufficient to cause death, particularly if the feeding punctures surround the stem. The effect of the toxin, injected at the time of feeding, is rapid, and if the feeding punctures are sufficiently numerous the young shoot will become flaccid within 48 hours, and will die. The fungus, *C. rigidiuscula*, apparently plays no part in this rapid destruction of soft stems attacked by the Capsids.

But observations on developing capsid lesions whether caused by *Sahlbergella* or *Distantiella* on hardened stems, combined with cultures from typical lesions have demonstrated profound differences between those lesions infected with the fungus and those free from infection.

In uninfected lesions the damage must be attributed to the toxin injected by the capsid and, to a small extent, to the mechanical effect of puncturing the plant tissues. The damage takes place mainly in the medullary rays of the cortex and only extends slightly into the medullary rays of the xylem. The medullary ray cambium is also destroyed, but there is very little damage to the phloem or phloem cambium. The lesion begins to heal about three days from puncturing. A wound

cambium is formed from medullary ray tissue in the cortex ; the primary cambium is reconstituted *in situ* and separates the damaged medullary ray tissue of the xylem from that of the phloem. As healing progresses, the dead tissues of the cortex dry out and fall away, leaving the dead phloem fibres adhering to the surface of the lesion in a characteristic net pattern. Healed lesions can be recognized by the absence of cankering and, at most, by a slight discoloration in the xylem. There is no evidence that uninfected lesions cause the bark roughening which was thought to be characteristic of healed capsid damage.

The development of the infected lesions follows an entirely different course. The initial toxin damage is similar, but the damage spreads, and after about two weeks there is extensive discoloration in the phloem. The damage in the xylem is more or less confined to the medullary rays ; the fungus mycelium is intercellular and avoids lignified tissues. The extensive damage precludes the reconstitution of the cambium *in situ*, and the lesion heals by the growth of callus tissue from the edges. These lesions are distinguished by a deep-seated canker extending to the xylem, and are associated with extensive discoloration in the xylem. All stems showing roughened bark have yielded *C. rigidiuscula* from lesions in the xylem which appear to mark the site of the original damage ; there is little doubt, therefore, that this symptom, too, is associated only with infected capsid lesions.

It therefore becomes evident that capsid punctures alone do not account for all the damage associated with " Blast." Even if all the young soft shoots on a tree were destroyed by capsids there would still remain some canopy formed by leaves attached to hardened stems ; but in areas of severe blast the canopy is completely broken and the leaves on the older stems are also killed.

The presence of *Calonectria* also helps to explain the formation of " Capsid Pockets". These pockets have been defined as areas of cacao, markedly localized, where intense perennial damage by capsids—mainly *Sahlbergella*—occurs. In these pockets the trees become stag-headed as a result of the death of the canopy twigs. In time the branches die and the trunk itself may be killed. Formerly, this die-back was ascribed entirely to repeated attacks of capsids, but it now seems certain that the destruction of the older wood is due to the presence of the fungus.

In order to assess the effect of damage on hardened cacao stems caused by *Sahlbergella* along and when associated with *Calonectria* an experiment was laid down by the Division of Pathology. The stems under examination were grouped into four classes.

Class I. Capsid lesions half ringing the stem.

Class II. Capsid lesions half to three-quarters ringing the stem.

Class III. Capsid lesions three-quarters or more ringing the stem.

Class IV. Capsid lesions completely ringing the stem.

The results are recorded in Table 11.

TABLE 11.

DAMAGE DUE TO CAPSID ATTACK ON HARDENED CACAO SHOOTS.

Class.	Infected Lesions		Uninfected Lesions	
	Number Recorded.	Number killed.	Number Recorded.	Number Killed.
I	5	—	10	—
II	14	—	5	—
III	14	3	9	—
IV	24	22	8	—
Totals	57	25	32	—

None of the stems with uninfected lesions showed any check in growth, but it will be noted that nearly half of those infected died.

Further notes on *C. rigidiuscula* will be found under Section VIII Mycology.

(2) Bionomics.

The bionomical studies carried out at Tafo in 1944–45 have been duplicated at Owena over the past twelve months. The longevity records are essentially the same at Owena as at Tafo and are recorded in Table 12.

TABLE 12.

	S. singularis.			*D. theobroma.*		
	Min.	Max.	Mean.	Min.	Max.	Mean.
Incubation period in days ...	16	19	18	14	17	16
1st Instar	3	5	4	3	9	4
2nd Instar	3	5	4	4	6	5
3rd Instar	3	10	4	2	5	4
4th Instar	4	9	5	3	5	4
5th Instar	5	11	7	2	7	6
Nymphal life	18	36	23	21	26	23
Period from egg to adult ...	35	52	41	38	40	39
Prematurity period	9	13	10	6	11	7
Longevity—adults to death ...	18	34	30	21	28	25

Both capsids have given similar results with regard to fecundity and records to date indicate an average of 50 eggs with a maximum of around 70.

Life History in Light and Shade.

It has often been noticed that both *Sahlbergella* and *Distantiella* appear to be attracted to breaks in the cacao canopy such as are caused by falling trees. Experiments were therefore laid down at Tafo and Owena to see whether sunlight had any effect on the life history. Gravid females of both capsids were caged on seedlings, some batches of which were exposed to sunlight, others kept in the shade.

As a general indication it appeared that both capsids laid more eggs in the shade. The work was discontinued at this stage as the temperature inside the cages was considerably higher than the temperature outside. This apparently caused such a high mortality in the gravid capsids in the sun-lit cages that true comparisons were rendered difficult.

Population Studies.

The routine capsid collections were continued in the Tafo neighbourhood six days a week—not twice a week as erroneously recorded in the First Annual Report. Population figures are sorted according to the source of the capsids, *i.e.*, whether found on foliage, pods or seedlings. A continual error occurs in the number of capsids in the foliage since the cacao canopy cannot be searched above hands reach.

The same collection technique has been adopted at Owena, but the scarcity of young cacao precludes the opportunity of gaining figures for *Distantiella*.

TABLE 13.

SAHLBERGELLA SINGULARIS POPULATIONS.

A = capsids per 100 pods.

B = capsids per 100 trees (foliage collections).

C = total capsids collected (on pods + foliage) per 100 trees.

Month.	TAFO			OWENA		
	A	B	C	A	B	C
April, 1945 ...	0·6	13·9	14·2	No records		
May	0·8	11·1	11·8	,,	,,	
June	1·2	8·2	9·5	,,	,,	
July	1·2	6·3	8·0	0·5	1·0	3·4
August	5·0	17·3	27·4	1·0	6·2	14·9
September ...	8·6	29·3	47·1	1·8	17·5	33·9
October	15·4	65·1	132·8	2·3	17·2	37·1
November ...	16·4	51·0	109·0	2·6	12·4	29·7
December ...	15·0	37·0	74·4	1·4	4·1	8·8
January, 1946 ...	20·4	46·1	67·2	0·2	3·3	4·3
February ...	27·9	30·6	43·7	1·1	3·0	4·7
March	23·8	17·2	24·8	2·6	5·9	13·2

TABLE 14.

DISTANTIELLA THEOBROMA POPULATIONS: TAFO.

Month.	Capsids per 100 seedlings.	
	1945–46.	1944–45.
April, 1945 ...	42	No record
May	40	,, ,,
June	29	,, ,,
July	33	,, ,,
August	56	23
September ...	54	29
October	54	42
November... ...	58	63
December ...	51	85
January, 1946 ...	65	133
February ...	41	109
March	20	57

Compared with the previous year the population of *Sahlbergella* on pods showed a rapid increase instead of decline during the period of pod scarcity after the bulk of the cacao had been harvested in November and December. The total *Sahlbergella* population reached its peak in October, 1945 compared with November, 1944. Even at the peak population the number of *Sahlbergella* corresponds to only some 800 bugs per acre.

The population figures for *Distantiella* remained remarkably constant throughout the year at Tafo and did not show a well-defined peak such as occurred in January, 1945.

Observations on Capsid Populations on Seedling Cacao.

An experiment to investigate the populations of *Distantiella* and *Sahlbergella* and their comparative proportions, on seedlings was started in December, 1945. Half an acre of three-year-old seedlings under mixed *Gmelina arborea* and *Leucaena glauca* shade on the old station were selected. Monthly observations were made when all the capsids on the seedlings were counted but not collected. Distinction was made between the various nymphal stages.

Results are given in Table 15.

TABLE 15.

MONTHLY CAPSID POPULATIONS ON YOUNG SEEDLINGS.

	D. theobroma.	*S. singularis.*
December, 1945 ...	53	33
January, 1946 ...	265	16
February ...	49	19
March	1	0
Total	368	68

The large increase in the *Distantiella* population in January, 1946, was almost entirely due to the large numbers of early instar nymphs, indicating that there had been a considerable amount of egg laying in December. The December collections showed a high proportion of adults but the actual number was the same as that for January when egg laying, as indicated by the February figures, was on a small scale. A probable explanation is that in January the seedlings entered their dry season resting stage and there was little production of suitable food material for the young nymphs. The preponderance of *Distantiella* on seedlings is well illustrated by the total figures.

At Akwadum, cacao planted in 1942, first became attacked by capsids in August, 1944, though only a few plants were affected. By January, 1945, no capsids could be found, but in June, 1945, nymphs were noted on two young cacao plants. In November the capsid population had increased considerably and hand-picking twice a month was commenced.

Table 16 shows the numbers of *Distantiella* and *Sahlbergella* caught and destroyed.

TABLE 16.

AKWADUM—CAPSIDS HAND-PICKED.

Date of collection.	Distantiella.	Sahlbergella.	Total.	No. of trees affected.	Av. No. Capsids per tree affected.
Nov. 1st Coll.	371	31	402	166	2·5
2nd ,,	527	4	531	231	2·3
Dec. 1st Coll.	504	34	538	227	2·4
2nd ,,	120	36	156	74	2·1
Jan. 1st Coll.	72	0	72	42	1·7
2nd ,,	433	11	444	125	3·5
Feb. 1st Coll.	216	17	233	98	2·4
2nd ,,	130	48	178	82	2·2
Mar. 1st Coll.	257	16	273	127	2·2
2nd ,,	101	2	103	50	2·1

The incidence of capsids is not uniform throughout the area, certain plots showing a heavier infestation than others. The presence of *Sahlbergella* on this young cacao is of interest.

The observations made at Tafo and Akwadum both confirm the contention that a low population of capsids can cause a great amount of damage.

General Incidence of Capsids.

The most noteworthy observation has been the general decline over the past year in the amount of capsid damage in Nigeria. Touring officers have reported that farms previously heavily infested with capsids —especially in the Ife District—are recovering. At Owena, where for many years capsid damage was most severe, it has been difficult to obtain the necessary number of bugs during 1945–46 for experimental work. The cacao on the Agricultural Department's farm at Owena, as a result of this reduction in capsid population, has improved considerably.

There is no factor to which this reduction of capsids in Nigeria can be definitely ascribed, but it may have been due to the severe and prolonged dry season of 1944–45.

In the Gold Coast no such general reduction in capsids has been noticed; at Tafo damage by *Sahlbergella* and *Distantiella* has been considerable.

Even in farms in the Gold Coast outside the forest belt—for example, on the Afram plains and in parts of Togo—capsid damage has, as yet, always been recorded. In Nigeria, however, certain cacao farms in savannah country—for example, near Iseyin in Oyo Province—no capsid damage, past or present, has been noted.

Alternative Host Preferences of Sahlbergella and Distantiella.

In one series of experiments the capsids were given a free choice between different alternative host plants in an insectary. The number collected or the number of times seen on each species was recorded.

In one experiment *Distantiella* and *Sahlbergella* released in an insectary containing equal numbers of cacao and silk-cotton (*Ceiba pentandra*) seedlings. At daily intervals thereafter the capsids were collected from the plants until no more could be found. The results are given in Table 17 and as can be seen both capsids prefer cacao, though *Distantiella* less so than Sahlbergella.

TABLE 17.

D. theobroma.	
Number liberated	= 816
Number recovered from cacao	= 339
Number recovered from Ceiba	= 203
S. singularis.	
Number liberated	= 844
Number recovered from cacao	= 317
Number recovered from Ceiba	= 86

In another experiment *Sahlbergella* females were given a free choice between equal numbers of seedlings of cacao, silk-cotton, *Cola cordifolia*, *Cola togoensis*, and *Uapaca sp.* in an insectary. Records of frequency on the different species, feeding and oviposition were made. Results of frequency and oviposition are given in Table 18.

TABLE 18.

C. = Cacao.
C.p. = *Ceiba pentandra.*
Up. = *Uapaca sp.*
C.c. = *Cola cordifolia.*
C.t. = *Cola togoensis.*

S. singularis.

	Frequency on each species.					Eggs laid.				
Number Liberated.	C.	C.p.	Up.	C.c.	C.t.	C.	C.p.	Up.	C.c.	C.t.
177	302	5	0	9	5	141	0	0	3	0

The overwhelming preference shown towards cacao is no doubt due to a certain extent to the greater succulence of the cacao seedlings.

A similar type of experiment but using a different technique was carried out at Owena. Cacao seedlings and alternative host seedlings were placed with the foliage contiguous and infested with equal numbers of capsid nymphs. Counts were taken twice a day to show the relative frequency with which the nymphs were found on the different plants. In one experiment cacao and silk-cotton were infested with *Distantiella* and in the other cacao, *Cola cordifolia* and commercial cola (*Cola nitida*) were infested with *Sahlbergella*. The experiments were on a small scale and no statistical evaluation of the results can be obtained. The results are given in Table 19.

TABLE 19.

D. theobroma nymphs.

Frequency of observations on cacao ... ...= 80
Frequency of observations of silk-cotton ... ...= 162

S. singularis nymphs.

Frequency of observations on cacao ... ...= 141
Frequency of observations on *Cola cordifolia* ...= 66
Frequency of observations on *Cola nitida ?* ... 84

It will be seen that the relative attractiveness of cacao and silk-cotton for *Distantiella* is the reverse of the results obtained at Tafo. Undoubtedly much depends on the relative succulence of the plants.

The role played by *Ceiba* as an alternative host of *Sahlbergella* and *Distantiella* under natural conditions in West Africa has received attention.

Ceiba is well known as an alternative host of *Distantiella* but in spite of intensive search *Sahlbergella* has not yet been observed on *Ceiba* in the field. In Sierra Leone observations suggest that there may be some correlation between the presence of *Sahlbergella* on cacao and the proximity of *Ceiba* but insufficient is known at present from which to draw definite conclusions.

In the Departmental cacao farms at Ina near Ibadan, Nigeria, *Distantiella* has not yet been recorded although it has been found feeding on *Ceiba* in the immediate vicinity of the farm. The cacao spacing experiment at Ina planted in 1942 is of great interest because neither *Sahlbergella* nor *Distantiella* has as yet been found although the experimental plot is surrounded on all sides by tall secondary forest in which *Ceiba* is present.

At Tafo no correlation has been proved between the presence of *Ceibas* and perennial centres of capsids on cacao.

During the year the search for wild hosts of the cacao capsids was continued and considerable time was devoted to this important phase of the investigations.

Previous records of damage to commercial cola (*Cola nitida ?*) were confirmed by the discovery of *S. singularis* nymphs and adults on this plant at Owena. Typical capsid damage, though far less severe than on cacao, was caused. An adult *S. singularis* was also seen feeding on a *Vernonia sp.* at Owena. Two nymphs, almost certainly those of *S. singularis*, were collected from a sucker of a stumped *Cistanthera papaverifera* at Tafo. Considerable attention was paid to the search for *S. singularis* on *Cola togoensis* but without success. Typical capsid damage on this plant was, however, found at Owena. Also at Owena *Cola cordifolia* was found to be damaged in a manner akin to that caused by capsids but no bugs were found.

S. singularis will feed and oviposit on this plant. Typical leaf damage similar to that caused on many plants by *Helopeltis* spp., was found on a species of *Uapaca* in Nigeria. *Uapaca* is given as the host plant of *Sahlbergella maynei.*

Observations on Capsid Pockets.

A number of capsid pockets was kept under observation and collections from them made every fortnight. The object of this was to determine the species of capsid present, the ratio where both species were found and the relation to the age of the trees; to follow population fluctuations; to determine whether capsids were always present. In addition, observations were made on the hatching of eggs in the pockets and on the mortality of the resulting nymphs.

The results of the fortnightly collections are shown in Table 20A.

TABLE 20A.

FORTNIGHTLY COLLECTION IN CAPSID POCKETS.

Month.	Number of capsids collected.	
	S. singularis.	*D. theobroma.*
September (one week) ...	105	63
October	1,764	517
November	2,533	1,482
December, 1945	2,763	1,067
January	2,994	1,541
February	2,115	729
March	202	36
Total	12,476	5,435

The artificial reduction of the population by collecting vitiates to some extent the value of the records as regards fluctuations of population, but the total figures indicate the preponderance of *Sahlbergella* in the pockets, although *Distantiella* is associated to a surprisingly large extent.

TABLE 20B.

Approximate Age of cacao in years.	Percentage of *S. singularis.*	Percentage of *D. theobroma.*
5—10	10	90
10—15	36	64
15—20	80	20
20—25	80	20
25—30	88	12

This confirms the general impression regarding the preference of *Distantiella* for young cacao, but at the same time shows that *Distantiella* is of some importance even in the older cacao.

The results of the observations on eggs and nymphs are given in Tables 21 and 22 and the daily decline in numbers shown by a more detailed investigation on a selected batch of 299 nymphs is shown in Table 23.

TABLE 21.

PERCENTAGE HATCH OF EGGS.

Total number of eggs found	= 1,541
Total number of eggs hatched	= 763
Percentage hatch	= 49·5

TABLE 22.

PERCENTAGE LOSS OF NYMPHS.

Total number of nymphs	...	...	... = 749
Total losses of nymphs	...	...	... = 367
Percentage loss	...	...	... = 49

TABLE 23.

DAILY LOSS OF NYMPHS.

Days.	Nymphs present.
1st	299
5th	298
6th	289
7th	275
8th	268
9th	261
10th	252
11th	237
12th	222
13th	193
14th	163
17th	156
18th	150
19th	144

Many eggs had already hatched before they were found so the apparent hatch of 49·5 per cent. is in fact well below the true hatch which is probably nearer 100 per cent. Likewise the loss of nymphs does not necessarily represent mortality as some may have wandered away. However, from the number of predators such as assassin bugs, mantids and spiders, seen preying on the nymphs it is likely that they accounted for most of the losses.

Biological Control of Capsids.

Investigations on biological control have proceeded along two main lines. Firstly, an intensive study of alternative hosts has been carried out in the field and laboratory to find out the primitive ecological habitat of the cacao capsids. As far as *Distantiella* and *Sahlbergella* are concerned little of outstanding importance in this connection has as yet been discovered. Secondly, visits have been made to Sierra Leone and to the Belgian Congo in a search for capsid parasites. The prospect at the moment is not very encouraging.

Work on the known parasite of *Sahlbergella*—*Euphorus Sahlbergellae*, Wilk. and its hyperparasite *Mesochorus melanothorax*, Wilk. continued at Tafo and was commenced at Owena. Table 24 shows the percentage parasitism at Tafo and Owena. The percentage of hyperparasitism is only given for Owena since the records at Tafo lack reliability, on account of the training of new staff.

TABLE 24.

PERCENTAGE PARASITISM OF S. SINGULARIS AND PERCENTAGE HYPERPARASITISM OF E. SAHLBERGELLAE.

	TAFO	OWENA	
	Percentage Parasitism.	Percentage Parasitism.	Percentage Hyper-parasitism.
April, 1945 ...	15·7	No record	No record
May	12·2	,,	,,
June	6·8	,,	,,
July	6·1	,,	,,
August	7·8	,,	,,
September ...	12·6	21·6	3·8
October	15·7	28·0	14·2
November... ...	11·9	15·0	17·7
December ...	12·3	12·4	11·6
January, 1946 ...	20·4	15·4	14·5
February ...	22·4	14·8	13·9
March	32·1	29·5	6·2

The figures for parasitism show a similar trend to those recorded in the previous year.

Bionomics of Euphorus Sahlbergellae.

The heavy pupal mortality mentioned in the last Annual Report has not yet been overcome and no progress has been made on the elucidation of the life history of *Euphorus*.

However, from experiments carried out at Owena it appears that a promising line has been discovered. Unfortunately it has not been possible to follow up this work yet as the supply of parasites failed with the fall of the host population. Mature *Euphorus* larvæ were allowed to spin their cocoons in dry sand and were then transferred to damp humus. Under these conditions eleven out of sixteen unhyperparasitised cocoons hatched compared with very small numbers in other treatments.

Egg Parasites.

An investigation into the possible presence of parasites of capsid eggs was started at Tafo. Adult females are caged on small cacao branches until eggs have been laid. The cage is then removed and the eggs exposed to natural infection. Careful watch is kept on the eggs and those which fail to hatch are dissected in the laboratory by a skilled assistant.

Predators.

Mantids, spiders and the Reduviid assassin bugs have been observed to prey on *Sahlbergella* and *Distantiella* in the field, but a numerical evaluation of their predatory activities remains to be explored.

Further work has been done in connection with the ant *Macromischoides aculeatus*, Mayr. which is believed to control the two capsids. This ant builds carton nests on the underside of leaves of a large number of trees and shrubs and is commonly found on cacao. A serious disadvantage in using *Macromischoides* as a method of control is that the nests are colonial and the queen is found only in one of a large number. Thus colonizing a cacao tree by direct transference of nests is valueless unless the queen is present. In order to test the possibility of speeding the colonization of young cacao, *Lonchocarpus*—a tree observed frequently to harbour *Macromischoides*—has been interplanted through four-year-old cacao severely blasted by capsids. The *Lonchocarpus* is not yet large enough for colonization by *Macromischoides*.

Chemical Control.

The use of D.D.T. and 666 (Gammexane) as an insecticide against capsids on cacao is still limited by the absence of suitable solvents and emulsifiers. In order to apply D.D.T. in sufficient strength as a spray it is necessary to obtain a solvent other than Kerosene; experiments carried out at Tafo show that the emulsified Kerosene solution diluted to the minimum at which D.D.T. is effective has a harmful effect on the cacao leaves and young stems.

Samples of dispersible D.D.T. paste arrived in poor condition and could not be satisfactorily resuspended. Dispersible powder containing 50 per cent. " 666 " showed some promise, but the need for constant agitation in the spraying machine is a drawback. We are now awaiting the arrival of other solvents and emulsifiers.

During the year routine spraying of young experimental cacao at Tafo was practised utilizing a nicotine solution. The minimum dilution of Nicotine sulphate (40 per cent.) found to be effective against both *Sahlbergella* and *Distantiella* was 0·1 per cent. From the start defects appeared in the pneumatic knapsack spraying machines, a consignment of which arrived in the latter part of 1945. The machines are of the pressure retaining type and are both heavy and cumbersome. An efficiency test on these machines after three months use showed that it took as long to pump air and insecticide into the container as it took to expel the insecticide through the nozzle. For West African conditions the provision of a simple, robust, high efficiency spraying machine is a real necessity.

A major cost in spraying is the transport of water. During the day the nymphs and adults of both *Sahlbergella* and *Distantiella* hide in crevices of the bark, in leaf axils or in the junction of stem and branch. The number of capsids per tree is small; consequently, if spraying is to be effective, it must be done very thoroughly and that means an enormous wastage of spray which never reaches the capsids. Preliminary experiments have therefore been started to test the application of preparation of D.D.T. and " 666 " to the stems of young cacao trees by means of a paint brush.

Cacao Resistant to Capsids.

Work on possibly capsid resistant types of cacao has been held up pending the production of sufficient clonal material of the selections. The whole problem of resistance has been complicated by the recent information gained in connection with the fungus *Calonectria*. Resistance can imply any of the following : unpalatability, an unsuitable medium for oviposition. resistance to the fungus or resistance to the toxin.

The progeny of the Nigerian cacao selection T.38 has shown field " resistance " to capsids at Tafo, but has been severely attacked and shown the symptoms of fungal infection at Owena. Nevertheless, difficulty has been experienced at Owena in breeding capsids on T.38 progeny.

Capsid Damage in Relation to Soils.

In cacao areas of comparable climatic conditions observations do not suggest any correlation between the degree of capsid damage and soils, though there is evidence that recovery is delayed where the soil moisture status is poor. At Akwadum capsid collections are recorded plot by plot and a high incidence in numbers and in the damage caused occurs in certain plots on all of the three main soil series.

Forest Enumeration.

The forest in the Nigerian Akure Reserve near Owena differs in many respects from that around Tafo. Many widely distributed species such as *Triplochiton scleroxylon*, *Ceiba pentandra*, *Terminalia superba* and *Cola cordifolia* are common to both. But *Piptadenia africana* very common around Tafo, has not been seen in the Akure Reserve, although it is common near Ife further north. Conversely *Brachystegia* spp. are absent from Tafo although common at Owena. The under-storey of the Akure Forest contains a very large proportion of *Uvaria* spp. (Anonaceae) and a *Cola* sp., probably new, which has not been recorded from the Gold Coast. This *Cola* is often found as a dominant on well drained areas of ground.

To obtain a numerical estimate of the composition of the forest around Owena, an enumeration of two one-acre blocks was made. Subsidiary objects were to obtain a series of named trees which would be of use in training new assistants, and to discover the presence of unsuspected alternative host plants. In this latter respect fortunately there was found a specimen of *Mereya spicata*, an alternative host of the green-nymphed cacao *Helopeltis*. This was previously unknown in the area. The ecological knowledge gained was, of course, valuable.

One of the enumerated blocks was on low ground by the Owena river, the other being situated higher up near the top of a slope. Transects were made from acre boundary lines and the trees inserted on a spot plan by pacing offsets. This work and the identification of the species was carried out by a Technical Assistant, to whom credit is due.

Bryocoropsis Laticollis, Schum.

This capsid is a minor pest of cacao in certain parts of the Gold Coast. The damage it causes is confined to the pods, and rarely has it been recorded attacking the shoots or stems of cacao in the field. The alternative host plant in the Gold Coast has been recorded as *Uvariodendron* sp. but the capsid was unknown in Nigeria. During the year special attention was paid at Owena to examining anonaceous plants in the adjoining forest. This led to the discovery by a Technical Assistant of *B. laticollis* feeding on the fruits and flowers of *Uvaria* sp. Both nymphs and adults were present. The damage caused to the *Uvaria* fruits was not as extensive as that on cacao pods upon which *B. laticollis* were found to feed readily but not to oviposit.

The regular capsid collections from cacao at Owena have failed to reveal the presence of *B. laticollis*. It is noteworthy that this capsid was first found on cacao in the Gold Coast in 1939 and observations suggest that its range on cacao is still limited to the Eastern and Central Provinces.

The discovery in Nigeria is of fundamental importance. We now have a specific instance of a capsid in its true ecological habitat before the change over to cacao.

IV. SOILS IN RELATION TO DISEASE; SOIL SURVEYS.

Considerable progress has been made during the year in connection with investigations into the soils on which cacao is grown in West Africa. The principal objects of these investigations are as follows :—

To determine (*a*) whether soil factors are in any way responsible for the development and occurrence of virus disease of cacao and (*b*) whether edaphic conditions in any way modify the effects of these diseases.

To discover (*a*) to what degree edaphic conditions may influence the distribution of capsid infestations of cacao and (*b*) to what extent soil factors may affect the damage resulting from these infestations.

To define (*a*) which soils now planted to cacao are really suited to this crop and (*b*) which soils as yet unexploited can be recommended for cacao cultivation.

Soil and Virus Disease of Cacao.

The great majority of areas in which swollen-shoot has been recorded has been examined in relation to the soils on which diseased trees were present. Up to the present, virus disease has been found in the Gold Coast among cacao growing in topographical sequences of earths developed over the following types of rocks :—Granodiorites, Quartzose granites, Basic igneous, Phyllites and Greywackes, Sericite schists, Clay shales, Consolidated Sandstones and Argillaceous grits, River alluvium, Earths developed from old termitaria. Thus swollen-shoot has been shown to occur on practically all soils on which cacao is grown in West Africa, and there is little doubt the disease will, in the course of time, be found infecting cacao on every earth of sufficient extent.

The earths recorded above differ very widely among themselves. With regard to water supplies they include soils with excellent moisture relationships, soils subject to rapid drying and soils perennially waterlogged. Moreover, the nutrient relationships cover an equally wide range including soils derived from basic igneous rocks with good lime but poor potash supplies, soils from rocks with ample potash and soils with ironstone concretions suggesting a shortage of phosphate. In fact, swollen-shoot has been found to occur on soils of widely different fertility status in the field and, of course, the disease has been induced in cacao grown in the artificial soils used for potting.

Observations of the soils in which cacao infected with swollen-shoot was growing also showed that soil deterioration, such as might have occurred through erosion or exposure, was absent.

Each locality where swollen-shoot has been recorded is often associated with one or more specific strains of the virus, but there is no evidence for and much against, the view that these different strains of the virus, and their effect on cacao, are influenced by the type of soil on which cacao is grown. The overall picture of cacao farms attacked by the virulent Strain A is worse on poor soils than on good, but that is because the cacao would, even without the virus, appear unhealthy—particularly in times of drought.

Thus we can now answer one of the major questions that arose in connection with swollen-shoot disease. The opinion has been expressed elsewhere that this disease might well be mainly associated with inherently poor soils, or those degraded by bad agricultural practice, but the work of the Division of Soil Science has shown that there is no evidence for this view.

Soil and Capsid attack. Capsids have been noted attacking cacao on every earth on which this crop is grown in West Africa, and it can therefore be stated that edaphic conditions have nothing to do with the occurrence of these pests.

It is a well established fact that the distribution of capsid damage is patchy and that it oftens occurs in well defined " pockets". Whether these " pockets " are the result of a permanent concentration of capsids or are the result of infection, following capsid attack, by the fungus *Calonectria rigidiuscula* remains to be established. If the former it is possible, but unlikely, that soil conditions are of primary importance ; if the latter there is a strong probability that the water relationships and nutrient status of the soil will affect the spread of the fungus in the tree.

In any event it can be stated that recovery from capsid attack will be quicker on soils well suited to cacao, but the evidence at present suggests no relationship between the presence of capsids and soil type.

Soil Survey. Three types of survey are being employed :—

1. A preliminary soil survey of West African cacao soils, having as its object the identification of the principal soils, their distribution, and the environmental conditions under which they occur.

2. Reconnaissance soil surveys, based on the principles of regional survey and using drainage basins of the cacao producing areas as units on which to work and having as their object the production of medium scaled maps showing the distribution of the principal soils or groups of soils.

3. Detailed soil surveys of selected areas of special importance, *e.g.*, experimental stations and plots and areas of special interest in connection with the growth, yield or incidence of disease and pests of cacao. These surveys would lead to the production of large scale maps accurately depicting the soil boundaries.

The Preliminary Soil Survey. This was commenced in December, 1944 and completed in March, 1946. Much information of value was given by the Nigerian and Gold Coast Departments of Agriculture and by the respective Geological and Survey Departments. This information together with a review of previous West African soil work and related subjects allowed a comprehensive summary of the existing knowledge of soils in the cacao belt.

Extensive tours were made to cover the forest belt of Nigeria, the British Cameroons, Togo and Dahomey and the Gold Coast. Some 400 soil profiles were examined and approximately 300 rock samples have been collected and labelled for reference.

General Topography of the Cacao Belt. By far the most widespread physiographic form occurring in the cacao belt is the peneplane, consisting of gentle undulations separated by relatively small drainage channels. Associated with this land form are characteristic topographical sequences of earths which are of great importance. Steep, broken or mountainous land and flat alluvial plains are of little importance because of their rarity.

General Climate of the Cacao Belt. Much data has been, and is being, collected from meteorological records in the cacao belt. Total rainfall, and its distribution, have a pronounced effect on the evolution of soils. Reliable meteorological data are necessary for assessing the value of soils as media for cacao production.

Parent Rocks and Soils. The preliminary cacao soil survey has been based on close examination of the rocks from which the soils have been derived.

1. *Acid Igneous Intrusions.* By far the greater amount of cacao in West Africa is grown on earths derived by weathering *in situ* of acid igneous intrusions. These comprise two groups : (A) the Granodiorites and gneisses of similar composition and (B) the Granites.

Group A. The rocks of this group consist of quartz, feldspars (potash, soda and soda-lime feldspars) biotite and hornblende. Owing to their relatively small content of quartz they give rise the clayey earths which are well supplied with plant food and able to conserve moisture satisfactorily during prolonged dry periods. They undoubtedly form the most productive cacao soils in West Africa.

Group B. The rocks of this group consist of quartz, feldspars (mainly potash feldspars) biotite and muscovite. Owing to the high proportion of coarse, granular quartz they contain they give rise to gritty sandy earths low in clay, easily leached and incapable of conserving moisture satisfactorily during rainless periods. They do not form good media for permanent cacao production.

The divergent opinions on the value as cacao soils of the earths overlying the granito-gneisses of the Cape Coast Complex may be explained by the association of these two groups of rocks.

2. *Basic Igneous Rocks.* Andesites, Gabbros, Dolorites, Basalts and Basic Ashes. Fairly extensive earths developed over these rocks occur in the Gold Coast, the Ivory Coast and British Cameroons ; they are of insignificant extent in Nigeria. In general these rocks give rise to productive cacao soils provided they are not weathered too deeply, but the impression has been gained that the soils are not so ideally suited to cacao as are those derived from Granodiorites and Gneisses of somewhat similar composition.

3. *Phyllites.* Soils from these rocks occur extensively in the cacao regions of the Gold Coast and also of the Ivory Coast. Phyllites are metamorphosed sedimentary rocks midway between slates and mica schists ; they consist mainly of quartz flour, sericite (a metamorphic form of muscovite) and albite (soda feldspar). Inherently these rocks contain little of value as plant nutrients and the soils derived from them owe most of their fertility to the accumulated surface humic layer characteristic of soils long covered by forest. Phyllites give rise to soils of good mechanical structure.

4. *Greywackes.* These rocks are often associated with phyllites, but are unrepresented in the cacao areas of Nigeria. Derived by metamorphosis of rocks of quartzite character, Greywackes consist of grains of quartz, soda or soda-lime feldspars, some sericite and muscovite and sometimes biotite and chlorite. They weather to red or brown clays but little is known of the value of these earths for cacao cultivation. Probably they resemble earths derived from phyllites in this respect.

5. *Sandstones.* These can be grouped into consolidated, typical of the Tarkwaian, Akwapimian, Buem and Voltaian of the Gold Coast, and unconsolidated, typical of the Colony sedimentary group and lignite group (Benin sands) of Nigeria. The unconsolidated have been derived from the leached end-products of weathered gneisses and granites and would not be expected to produce soils of inherent fertility. Equally the consolidated sandstones have little plant mineral value though certain of the Tarkwaian are composed of feldspathic particles and should give rise to more fertile soils. The water relationship of soils derived from consolidated sandstones is poor and cacao grown on these soils is subject to drought.

6. *Clay Shales.* These are of little importance in Nigeria but occur to some extent in the Gold Coast cacao belt. Produced as a highly

leached end-product of the weathering of other rocks they give rise to soils of poor inherent fertility.

7. *Schists.* Generally these, which occur in the Gold Coast, Togo and in small areas in Nigeria, give rise to soils of low inherent fertility and are subject to rapid drying.

8. *Limestones and Calcareous sandstones.* These are of such limited extent that they can be disregarded.

9. *Recent Alluvium.* Recent river alluvia occur as small strips by the sides of drainage channels throughout the West African cacao belt. Their suitability for cacao varies greatly.

It will be noticed that stress has been laid on the mineralogical composition of the parent materials of the various earths. This is due to the fact that the permanent productivity of an earth is governed by the nature of the rock that has given rise to it. Productivity is mainly determined by (*a*) texture, on which moisture relationships depend, which is wholly controlled by the character of the parent rock and (*b*) nutrient status which is determined primarily by the presence or absence of minerals which on weathering release readily-available plant food. Thus coarse grained quartzose granites give rise to sandy, droughty earths while basic igneous rocks, containing no quartz, give rise to clay soils with good moisture retaining properties. Similarly soils from granites are well supplied with potash which is liberated by the decomposition of black mica and potash feldspars—components of granite. But basic igneous rocks contain little or no potash though they are well supplied with lime-containing feldspars and pyroxenes. Soils derived from basic igneous rocks are therefore short of potash but have ample lime.

It is often stated of the tropics that weathering is so intense and proceeds to such a depth that decaying rock and minerals are quite beyond the reach of roots of many crop plants, but this is by no means at all general. In West Africa, earths from both granites and basic igneous rocks, for example, both contain plenty of boulders and stones of the parent rock in varying states of decomposition which, as mere observation shows, is being accomplished with the aid of fine plant roots forcing their way into the crevices and layers of the rotting rock. In what are perhaps the most productive cacao soils of West Africa, those derived from granodiorites and gneisses of similar composition, the incompletely-weathered rock is almost always within easy reach of the terminal rootlets of the tap. Some earths do, however, weather deeply and the little-decomposed parent rock is well beyond the range of the roots of most crops ; this occurs with some of the phyllite earths, but here, again, this feature is dependent on the nature of the source material.

Whilst the permanent or *inherent* productivity of an earth depends so largely on the nature of the parent rock, even the most sterile earths may have a high fertility for a few years after the forest they formerly supported has been felled. This fertility has been acquired as the result of forest growth over hundreds or perhaps thousands of years and the vegetation has, as the earth weathered and was worn away, concentrated

the small quantities of nutrients it contained in the surface humous layer to such an extent that the trees may eventually be supported entirely by this organic zone and be quite independent of the underlying material. This *acquired* fertility is ephemeral in character and quickly disappears, as a result of insolation and leaching, after removal of the forest cover. It is, therefore, a matter of the greatest importance to distinguish between inherent and acquired fertility. The danger of over-hasty conclusions about the value of an earth for crop-production based upon the luxuriant forest growth it carries is now, as a result of many spectacular economic failures, well known.

Conclusions of the Preliminary Soil Survey. The main cacao regions of British West Africa were visited and the rocks and soils derived therefrom examined.

As a result the following general classification of the various earths may be arranged in three groups :—

Group I. Soils which on account of their unsatisfactory moisture relationships coupled with inadequate nutrient status are unsuited to permanent cacao culture.

Group II. Soils which possess a satisfactory moisture status but are inadequately supplied with nutrients. These would require manuring if they are to be utilized for permanent cacao culture.

Group III. Soils which possess a satisfactory moisture status and which, by reason of the mineralogical nature of their parent material are inherently fertile. These soils are suited to permanent cacao culture with little or no amendment.

The soils in Group III are most suited to peasant exploitation ; those in Group II would require scientific methods of manuring, while those in Group I would be best utilized for other crops or forest.

Pedologically the earths of the cacao growing regions may be provisionally classified as follows :—

I. Leached Eluvial Earths ;

(*a*) With free drainage throughout the profile and devoid of ironstone concretions.

Concolorous red, brown and yellow earths.

(1) Siliceous earths.

(2) Sesquioxidic earths.

(*b*) With drainage impeded in the lower parts of the profile and characterised by their content of ironstone concretions.

(1) Eluvial mottled earths.

(2) Ferruginous red earths.

(*a*) Ferruginous sandy earths.

(*b*) Ferruginous brash earths.

II. Leached Colluvial Earths ;

(1) Completely weathered earths.

(2) Skeletal or bouldery earths.

III. Leached Illuvial Earths ;

(1) Illuvial mottled earths.
  (*a*) Juvenile
  (*b*) Senile.

(2) Predominantly grey subaqueous earths.

IV. *Biogenic Earths.*

Weathered termitaria.

Reconnaissance Soil Survey.

A start has been made on the reconnaissance soil survey, but the results will be recorded in the next annual report. This survey is being based on lithologic collections and examinations of profiles. The results of these superimposed upon topographical maps will allow the production of soil maps of sufficient accuracy to demarcate areas suitable for permanent cacao culture.

Detailed Soil Survey.

Though Detailed Soil Surveys should succeed and not precede the reconnaissance survey it was essential to obtain a detailed soil map of the Institute's land. This has now been completed. Less than half the area has been found to be sufficiently uniform for critical experiments. Twelve soil series occur and these have been accurately mapped and described.

A detailed soil survey of the Department of Agriculture's proposed experiment station near Kumasi has been commenced.

Staff Training.

It is particularly gratifying to record the progress made in training African staff in soil surveying. Several have shown exceptional keenness and aptitude for this type of work.

V. EXPERIMENTAL PLOTS IN NATIVE FARMS.

The object of these experimental plots was stated in the First Annual Report.

Akwadum.

During the year it was decided to alter the scope of investigations at Akwadum ; sixteen acres had previously been planted with the object of ascertaining whether cacao could be re-established in swollen-shoot devastated farms and of gaining information on the rate of spread of swollen-shoot and capsid pests of young cacao. Seed at stake was planted in 1942 and growth has generally been excellent, so much so that Akwadum proved an invaluable demonstration of the potentialities of replanting cacao in devastated areas. After consultation with the Department of Agriculture it was agreed to keep this 16 acres for demonstration and to take measures to prevent the spread of swollen-shoot and capsids. The loss of exact data on the rate of spread of disease and pests will be counter-balanced by the gain in the value of successful re-establishment.

Certain areas in the 16 acre plot are backward, and it is believed these areas correspond to land heavily food farmed after the death of the original cacao (through swollen-shoot) and before the Department took over. In March, 1946, a number of young trees was flowering, and in several plots the cacao had formed a canopy. The ingress of swollen-shoot —five plants—and capsids has been noted previously in this report.

NANKESE.

This farm of some 18 acres was taken over at the request of the owner in 1944. It had been planted with cacao in 1908 and subsequently destroyed by swollen-shoot. After removing the few remaining diseased cacao trees, shade was planted where the natural vegetation was poor—in particular in areas farmed in 1944 with cassava, okras or peppers. Cacao was planted at stake, three seeds to a stand, 5 ft. by 5 ft., in March and April, 1945. In the food-farmed areas germination and subsequent growth was poor and heavy supplying was necessary later in the year. In other parts of the farm particularly under oil palm shade growth has been good. The seedlings came through the dry season well and a marked improvement has now taken place in the young cacao plants situated on the old food farms. No seedling has shown swollen-shoot disease symptoms and capsids have not yet appeared. There are an estimated 60,000 seedlings in the farm.

KUKUA.

This farm is situated in a district more recently but just as severely infected with swollen-shoot as Nankese. The area of the farm is 30 acres divided by a road into one portion of eight acres and the other 22 acres. The original treatment has been similar to that adopted for Nankese, but it is proposed to take no control measures against swollen-shoot or capsids on the eight acres, but to record their ingress and rate of spread and to make other pertinent observations. On the remaining 22 acres control measures will be taken.

Cutting out dying and diseased cacao trees was completed in May, 1945—over 10,000 trees were removed. Ceibas and *Canthium* were also destroyed. Temporary shade was established and cacao planted at stake as conditions permitted throughout the wet season of 1945. The spacing adopted was the same as that employed at Nankese.

Variability has been shown in the growth of the seedlings according to the degree and locality of previous food farm areas. But in general the cacao passed the dry season well and growth is satisfactory. Out of an estimated 90,000 seedlings none has shown swollen-shoot symptoms or capsid damage.

ADUNKWANTA.

This farm is situated within seven miles of Tafo and is divided by a road. Ten acres on one side of the road are to receive control measures against swollen-shoot and capsids and 10 acres on the other side left for observations such as will be taken on the eight acres at Kukua. At

the repeated request of the owner the Institute has agreed to extend the area by three acres on either side of the road. The total area is now, therefore, 26 acres.

The farm was the last to be taken over and the removal of diseased trees did not start till June, 1945. Many showing early symptoms were left until the main crop was harvested and were then cut out. Cacao was planted as at Kukua and Nankese, but late in the year. As a result the seedlings are not so far advanced as on the other experimental plots, but are generally satisfactory. Again establishment is being found to be more difficult on areas previously food-farmed or where grass is the dominant ground flora. No symptoms of swollen-shoot or capsid damage have been recorded on the estimated 70,000 seedlings.

KORANSANG.

On this experimental plot an endeavour is being made to preserve what remains of healthy mature cacao on an area of 20 acres surrounded, as are the other experimental plots, by diseased cacao. Details of the control measures have been recorded under Section II, Virus Research. Vacancies caused through cutting out diseased trees have been filled by seed sown at stake or by seedlings grown in nursery beds. Part of the the farm is subject to drought and seedling losses were high in that area during the dry season. Generally the cacao seedlings have grown satisfactorily. Three have shown virus symptoms and have been rogued.

Apart from the information concerning the incidence and control of swollen-shoot and capsid pests that we shall obtain from these experimental plots, we are already gaining much needed experience in connection with cacao agronomy.

VI. INTRODUCTIONS.

A list of the types of cacao introduced from Trinidad and of allied species from Brazil was given in the last Annual Report. These seedlings were planted out in their permanent sites in June, 1945, by which time the greater vigour of the Upper Amazon types was already outstanding. It was not possible to establish adequate shade before planting the cacao, but in spite of this the plants have survived a severe dry season remarkably well. Only 3 per cent. of the plants have died, and most of the survivors are now growing strongly. Losses were greater among the allied species as was expected, because many of these plants suffered severely from soil deficiencies in the Quarantine House. Fortunately the losses occurred among those species best represented in the collection, and with the exception of *Th. angustifolium* and *Th. subincanum*, adequate numbers of seedlings of each species are now becoming established. The plants were regularly sprayed with Nicotine sulphate to destroy capsids and other harmful insects.

VII. BOTANICAL AND HORTICULTURAL STUDIES.

PROGENY TRIALS.

These trials, which were described in the 1938–42 Report of Tafo Station (Gold Coast Department of Agriculture 1943), have been

maintained. The first and second trials are of particular interest as those plots which have escaped severe capsid damage are coming into bearing, while on others the cacao plants present the typical "blasted" appearance caused by *Distantiella theobroma*. There is some consolation to be derived from these devastated plots, however. Certain seedlings consistently escape severe damage, and except in the case of those infested with the ant, *Macromischoides* sp., there appears to be no reason other than that they are unsuitable for oviposition or feeding of the capsid, or are resistant to the fungus *Calonectria*. These progeny trials therefore provide a basis for the development of resistant varieties, and some of the most promising plants have been propagated by budding to provide clones for further resistance tests.

Propagation.

The work on propagation of cacao by cuttings has been progressing steadily during the last year. Satisfactory rooting has been obtained but not maintained. This is presumed to be due to seasonal variation as a corresponding variation was noticed during the previous year. Suitable material was in very short supply during the October–November period and during March. This affected the rooting percentage as will be seen from Table 25.

TABLE 25.

Month.	Percentage cuttings rooted.	Root length per cutting in inches.
January, 1945 ...	45	8
March	40	3
May	65	3
July	59	5
September	67	4
November	45	3
December	50	3
January, 1946	61	6
February	70	5
March	65	5

This shows that only about 60 per cent. of the cuttings have rooted but the percentage for March, 1945, was 25 per cent. less than that of March, 1946, although there is a corresponding drop in both from the previous month.

A series of experiments has shown that conditions are best for rooting when :

(*a*) the cutting carries a recently hardened flush.
(*b*) the buds are dormant.
(*c*) the cuttings are about 10 ins. long.
(*d*) the leaf area is reduced by one-third.
(*e*) the propagator bins are shaded with cheese-cloth.
(*f*) unsifted coarse river sand is used.

There is a very noticeable difference between cuttings of the Trinitario and Amelonado clones. The Amelonado are usually less vigorous and have rooted at a consistantly lower rate than Trinitario clones. This difference is about 15 per cent. over a long period, and may account for our rooting percentage being lower than Trinidad figures.

Growth-substances have been used for a considerable part of the year giving 5–30 per cent. increase on the controls. It is not yet certain which of the chemicals being tried will give the highest percentage and the best root-growth. The concentrated dip for one second is as effective as the older and more difficult dilute dip for 24 hours. The former is 25 times the concentration of the dilute dip, and is much more convenient, quicker and simpler ; the expense is about the same.

Various other types of cuttings have been tried out in order to save material. Leaf-bud cuttings, which are cuttings consisting of one leaf and a small piece of stem attached, have been successfully rooted. They are uneconomic in spite of their small size as only about 25 per cent. root even with growth-substances. Dwarf cuttings about three inches long, are useful for multiplying certain clones quickly but not all clones will root well. Root-cuttings produced good roots in under one month when the base was smeared with a one per cent. indolyl butyric acid in lanolin paste. Those untreated rotted quickly. No shoots had been observed on the root cuttings after one month.

Hardening-off the plants after rooting has been difficult, but it is hoped that losses can be reduced now that adequate hardening bins have been constructed and experience gained.

In July, 1945, two new blocks of propagating bins were added making a total of 72 bins altogether. The plant barns have been improved by increased shade.

Pollination.

The study of cross-pollination, using the inheritance of axil spot, has been continued. During this year cross-pollination occurred only between adjacent trees, whereas in 1944 pollen was carried to trees three rows distant from the red-podded tree.

The insects chiefly responsible for cross-pollination of cacao have been identified by Dr. J. W. S. Macfie. They are the midges, *Forcipomyia ingrami*, Carter ; *F. ashantii*, Ingram and Macfie ; and *Lasiohelia litoraurea*, Ingram and Macfie.

The parallel with pollinating insects in Trinidad is interesting, as there, *Forcipomyia quasi-ingrami*, and *Lasiohelia nana*, Macfie, appear to be the chief cross-pollinating agents.

VIII. MYCOLOGY.

Mention has been made of the part played by the fungus *Calonectria rigidiuscula* (Berk. & Br.) Sacc. in connection with capsid attack.

It has been demonstrated by artificial inoculation with pure cultures that this fungus can be established in healthy cacao trees if mechanically wounded. The spread of the fungus after inoculation is, however, very slow under these conditions. But if the trees have been weakened either by drought or repeated capsid attack the fungus may spread rapidly and cause spectacular dieback.

C. rigidiuscula has three distinct types of spores ; the two conidial stages have been described as *Fusarium decemcellulare*. All three types occur commonly in the Gold Coast. The microconidia occur on the mycelium which sometimes grows over recently infected tissue, especially capsid lesions on green stems. The macroconidia are borne on small pinkish-buff sporodochia which emerge through the bark on recently dead stems. The perithecia are borne in groups on small stromata on stems that have been dead a long time and are of the same colour as the sporodochia and also emerge through cracks in the bark.

IX. AGRONOMY, TAFO STATION.

Cacao Crop.

Old Station. The Minor crop during the year under review was small with no clear cut division between it and the Major crop. Flowering and pod setting were good and pointed to a heavy crop, but yields were below expectations, due mainly to the high percentage of discarded pods caused by Helopeltis damage and to a prolonged period of high humidity at the peak of the growing season.

The first of four pickings was made in September.

Yield records for an area of 63·69 acres, *i.e.*, all the cacao on the Old Station, are given in Table 26 below, and it will be noted that the percentage of pods discarded prior to fermentation was double that for the eight year mean (1938–1945), and the yield of dried beans per acre was 28·8 per cent. lower than that of previous crop and 32 per cent. lower than the eight year mean.

TABLE 26.

TOTAL CROP FROM ALL CACAO (63·69 ACRES) ON OLD STATION 1938–1946.

Season	No. pods Harvested.	Percentage pods Discarded.	Total weight wet beans.	Percentage Dry to Wet weight beans.	Yield per acre Dry cacao lbs.
1938–39 ...	775,065	15·82	127,468	43·8	808
1939–40 ...	682,109	10·67	132,627	40·8	783
1940–41 ...	706,443	8·43	140,161	41·4	788
1941–42 ...	767,461	13·26	139,889	40·0	795
1942–43 ...	621,724	10·54	115,388	43·1	749
1943–44 ...	643,180	16·42	113,995	40·4	720
1944–45 ...	593,217	14·69	108,037	40·8	690
1945–46 ...	547,762	29·19	76,658	40·9	492
8 year mean	667,120	14·52	119,278	41·4	728

Yields on the recorded plots of the Uniformity Trial, comprising 225 one-quarter and 31 one-sixteenth acre plots, totalling 57·94 acres are shown in Table 27. No minor crop is recorded as such, but the figures are included in the first picking of Major Crop.

TABLE 27.

Crop.	Date of picking.	No. pods harvested.	Percentage pods discarded.	Wet weight Beans.	Percentage Dry to Wet.	Av. yield per acre dry cacao.
	1945.					
	Sept. 5–15 ...	41,802	30·3	7,472	36·8	47·5
	Oct. 1–31 ...	217,312	21·5	36,026	40·5	252·1
	Nov. 20–Dec. 12	238,095	34·3	26,906	42·24	196·2
Major	1946.					
	Jan. 4–17 ...	19,120	45·6	1,768	43·46	13·3
Total		516,329	29·0	72,172	40·8	509·1

Distribution of yields on 225 one-quarter acre plots is tabulated in Table 28, the class interval per plot being 50 lbs. (*i.e.*, 200 lbs. per acre). The modal class has fallen from 801–1,000 for the previous two seasons to 401–600 lbs. for the present season. The low yield on plot A.31 of ·73 lbs. per acre is due to heavy *Sahlbergella* damage throughout the plot, which has been effected over a period of years, forming a typical *Sahlbergella* pocket.

TABLE 28.

DISTRIBUTION OF 225 ($\frac{1}{4}$-ACRE) PLOT YIELDS 1945 TOTAL CROP.

Yield Class lb. per acre.	Percentage of total No. of plots in each class.		
	1943–44	1944–45	1945–46
0– 200...	3·6	5·8	8·5
201– 400...	9·3	9·3	25·3
401– 600...	17·7	23·1	35·1
601– 800...	17·3	22·7	19·1
801–1000...	18·6	24·4	8·0
1001–1200...	17·3	7·1	3·6
1201–1400...	10·9	4·9	0·4
1401–1600...	4·4	1·8	—
1601–1800...	0·8	0·9	—
1801–2000...	—	—	—
Highest Plot Yield in lbs. per acre ...	1644·60	1661·52	1251·76
Lowest Plot Yield in lbs. per acre ...	162·08	80·12	0·73

Trees which died or were removed for various causes including swollen-shoot during the year amounted to 923 or 3·3 per cent. of all trees on the Station.

One Square Mile Acquisition.

Having entered on the newly acquired land in August, 1945, the first picking was made in September, 59·25 tons of marketable cacao being harvested, a smaller quantity than was anticipated. Some pods had been harvested by the farmers prior to the acquisition, and 16,400 pods were supplied for planting on the Extension Plots ; these represented approximately 0·5 tons of dried beans.

Eradication of swollen-shoot infected cacao was embarked on and this phase of the work is dealt with in Section II, Virus Research.

Experiments.

(1) *Complete (N.P.K.) Fertiliser Trial on Average Cacao.*

This experiment which commenced in March, 1941 consists of a Latin square of four treatments, each replication containing 18 trees guarded by a double row of trees of the same age as those in the experiment.

The cacao was originally selected as being average for the Station and the trees had an average age of 18–20 years with a girth of 14 inches. The average density was 435 trees per acre.

Treatments.

P, K, KP and control with N imposed as half plot treatment.

P as 2 lbs. superphosphate per tree.

K as 2 lbs. sulphate of potash per tree.

N as 2 lbs. sulphate of ammonia per tree.

Control. No treatment.

Individual tree yields recorded as pods per tree.

After the second application of fertilizers the treatment was discontinued owing to the war-time absence of manures. Applications were resumed in May, 1945, the nitrogen being omitted from the treatments ; a second application was made in October, 1945.

Whilst no statistically significant results have been obtained between treatments it is interesting to note that tree yields based on number of pods per tree have increased on all treatments over the pod yields for the two pre-treatment years 1939–40 and 1940–41.

The control within the experiment has shown a decline, and a marked increase is in evidence on the treatment plots receiving phosphates. Data are given in Table 29.

TABLE 29.

YIELDS—PODS PER TREE.

Fertiliser.	Pretreatment		Pre-treatment Mean.	Treatment					1945-46 as percentage over Pre-treatment Mean.
	1939-40	1940-41		1941-42	1942-43	1943-44	1944-45	1945-46	
Control	27·1	21·9	24·4	23·2	21·7	25·2	22·3	21·5	−11·9
K.	12·2	19·6	15·9	20·4	17·6	18·2	17·5	17·9	+12·6
K.P.	15·9	17·3	16·6	21·4	21·0	24·0	20·7	21·4	+28·9
P	18·5	18·7	18·6	23·0	24·1	26·3	22·5	22·1	+18·8

(2) *Complete (N.P.K.) Fertilizer Trial on Young Cacao.*

Seedlings from two selected trees were used on this experiment and these were planted in May, 1942 with *Gliricidia* as shade.

Object.

To ascertain the effect of mineral fertilizers on the bearing age and yield of young cacao.

Layout.

Four randomized blocks of eight treatments. Each plot is one-sixteenth acre and contains 100 trees planted at 5 feet by 5 feet of which 36 guard row trees of mixed progeny surround 64 experimental trees made up of 48 uniform and 16 mixed progeny seedlings.

It is intended to thin to 10 feet by 10 feet at a later date in order that yields may be recorded from cacao of normal population density on maturity.

Treatments.

N : P : K : NP : PK : NPK : Control.

N = ½-lb. Sulphate of Ammonia in two applications per annum.

P = ½-lb. Superphosphate in two applications per annum.

K = ½-lb. Sulphate of Potash in two applications per annum.

The fertilizers on this experiment were applied for the first time in May, 1945, after the *Gliricidia* shade had been reduced by 50 per cent.

A second application was made in November, 1945.

It had been considered that the experiment might afford some evidence as to the effect of the fertilizers on capsid attack, but damage by *Distantiella* was so severe on all plots that spraying had to be carried out to save the trees.

(3) *Artificial Shade. Observational Plots.*

Artificial overhead and lateral shade were applied to established cacao in 1940 and 1941 to assess their effect on health, habit and yield. Observations on flushing, flowering, and pod setting, have been made on the shaded trees and on comparative trees outside the shaded areas.

Overhead Shade No. 1, *Erected June*, 1940.—Shade consisted of raffia cane mat allowing approximately one-third of the light to pass, suspended three feet above the canopy, the edges reaching down to the tops of the outer trees.

The cacao was 15 years old of average health and spaced at approximately 8 feet by 8 feet. Eighteen trees were recorded under this treatment.

Overhead Shade No. 2, *Erected January*, 1941.—Wider meshed mats allowing two-thirds of the light to pass. Trees 20 years old—average health, spaced at approximately 9 feet by 9 feet. Eighteen trees were recorded.

Lateral Shade, Erected May, 1940.—Cacao protected by bamboo and palm leaf screen 14 feet high on its exposed northern and western boundaries—trees 15 years of age. Fifty trees were recorded.

Data from these observations have been conflicting and it has been decided to discontinue them. One plot of shaded trees has shown a very marked decline in yield compared with unshaded trees outside the area as will be seen from the data given in Table 30.

TABLE 30.

ARTIFICIAL SHADE OBSERVATIONAL PLOTS.

Yield in Pods per Tree.

Treatment.	Pre-treatment Yield.	1941-42	1942-43	1943-44	1944-45	1945-46	Percentage + or — Pretreatment Yield.
Overhead Shade No. 1	5·2	4·6	3·2	4·9	1·8	5·3	+ 2·1
Overhead Shade No. 2	26·9	17·2	13·0	12·0	7·6	5·7	—78·0
Lateral Shade ...	10·1	25·9	28·5	16·8	14·0	16·9	+ 5·8
Control	20·6	29·2	25·7	22·3	17·1	24·8	+ 2·0

(4) *Rejuvenation Trial.*

The object of this trial, which was initiated in 1941, is to ascertain the most economic method of restoring cacao farms which have declined in yield through causes which might be ascribed to age, soil exhaustion, *Sahlbergella* damage or other factors.

Six acres of 25-year-old cacao which had been showing a steady drop in yield were selected for the trials.

Layout consists of 12 replicates of four treatments each plot being one-eighth acre.

Treatments were :—

(*a*) Mulching with material from outside the area, elephant grass (*Pennisetum purpureum*) being used. Wilted material at the rate of 16 tons per acre in two applications per annum.

(*b*) Leguminous ground cover and shade, *Leucaena glauca*, established from seed.

(*c*) Coppicing with supplementary shade —Plantains. Trees ring-barked at six inches above ground to promote chupon growth prior to coppicing.

(*d*) Stumping and replanting with *Leucaena glauca* shade. Spacing 10 feet by 10 feet. Seedlings of high-yielding selections being used.

Treatment (*a*) shows a steady decline in yield over the five treatment years.

In Treatment (*b*) a similar trend of yield is apparent.

Treatment (*c*) records show a 60 per cent. loss of the original trees as a result of the coppicing and to subsequent heavy damage by *Distantiella* on the water shoots.

Treatment (*d*) seedlings have made fair growth but have been severely damaged by capsids.

Table 31 summarizes pod yields in Treatments (*a*) and (*b*).

TABLE 31.

AVERAGE NO. OF PODS PER TREE IN TREATMENTS (*a*) AND (*b*). MULCH AND LEGUMINOUS COVER RESPECTIVELY.

Treatment.	1938-39	1939-40	1940-41	1941-42	1942-43	1943-44	1944-45	1945-46
(*a*) Mulch ...	36	34	No record.	38	29	28	26	20
(*b*) Leguminous cover ...	28	27	do.	36	24	24	22	15

None of the methods can be considered satisfactory.

(5) *Establishment Trials.*

Various methods of establishment were combined with the establishment of 16 acres of Amelonado progeny selections.

Four systems of temporary shading were originally decided upon, viz. :—

(i) Native method, following the practice of nursing the seedlings under mixed food crops for two or three years.
(ii) Plantains, *Tephrosia candida* amd Pigeon Pea.
(iii) Plantains alone.
(iv) Erect leguminous cover (*Crotalaria* spp.).

These treatments were later modified by using only plantains and cassava in Treatment (i) and substituting *Leucaena glauca* for *Crotalaria* spp. in Treatment (iv).

Layout consisted of 16 replicates of each treatment, each plot being a square quarter-acre in size. Each of six permanent shade treatments were planted on two contiguous acre blocks, being superimposed on two

replicates of each temporary shade treatment, four replicates of the latter being unshaded.

Permanent shade treatments are as follows :—

(1) Samanea saman spaced at 50 feet by 50 feet.
(2) Albizzia lebbek „ „ 50 feet by 50 feet.
(3) Tetrapleura tetraptera „ „ 50 feet by 50 feet.
(4) Peltophorum ferrugineum „ „ 50 feet by 50 feet.
(5) Gliricidia sepum „ „ 20 feet by 20 feet.
(6) Leucaena glauca „ „ 10 feet by 10 feet.

Temporary Shade.

Of the temporary shade treatments, the native method has shown marked superiority, judged from the standard of seedling growth and general health.

Plantain shade alone has proved inadequate.

Pigeon Pea in Treatment (ii) was difficult to establish and did not persist, and the plots were replanted with *Tephrosia.*

The plants in Treatment (iv) have made good progress since the *Crotalaria* was replaced by *Leucaena*, but have suffered severely from capsid attack.

During the year under review, some of the trees came into bearing and 1,008 pods were picked yielding 73·5 lbs. of dry cacao.

Pod yields from each treatment are expressed as a percentage of the total yield in Table 32.

Unfortunately the plots cover a wide range of soil types ; on the poorest of these the cacao never became established and certain of the plots have been abandoned.

TABLE 32.

Treatment 1	Native Method	68·2 per cent.
„ 2	Tephrosia	22·6 per cent.
„ 3	Plantain Shade only	1·9 per cent.
„ 4	Crotalaria replaced by Leucaena	7·3 per cent.

Permanent Shade.

From observations the Saman has made the best growth and provided the most suitable canopy for young cacao, 60 per cent. of the ground on the plots being effectively shaded.

Peltophorum ferrugineum gave approximately 40 per cent. effective shade whilst Albizzia *lebbek* and *Tetrapleura tetraptera* lagged behind at an estimated 30 per cent. and 20 per cent. respectively.

The shade from the *Peltophorum* is less dense than that from Saman.

Gliricidia and *Leucaena* have both provided excellent shade, but there is no information yet as to the number of years the trees will persist.

TAFO STATION.

General.

The 640 acres of the New Acquisition were taken over in July, 1945, and a further 35 acres for the accommodation of African Staff Quarters were given by the Tafo Stool in September.

The Square Mile has been developed by the provision of roads at quarter mile intervals at right angles thus dividing the area into 40-acre blocks. An eight foot boundary line was cut round the perimeter. Except the central road running S.S.W. to N.N.E., which is 20 feet wide, all roads are 12 feet in width.

Station Maintenance.

Routine sanitary measures were maintained but the anti-malarial control was intensified by the appointment of a skilled African Officer, trained by the Inter-Allied Malarial Control Authorities. All drains have been graded and oiled regularly and a programme of spraying the quarters and standing water with D.D.T. in kerosene was embarked on in February, 1946.

Repairs to bungalows and station buildings were carried out.

The grass cutting on the Old Station, which absorbed much more labour owing to the increased area, appears to have had some effect in reducing the sandfly population.

On the Square Mile, a division of the area has been made into four Sections. Each Section is in charge of a Technical Assistant and 35 labourers, *i.e.*, five acres per man, and these gangs are responsible for maintenance of all roads and established crops, including the harvesting of the cacao.

Readings of the flow of water over the dams on the Beyera were continued during the year.

Stocks of shade, hedge and ornamental plants were kept in the nurseries.

Fifteen acres of food crops were grown on newly cleared areas prior to grassing down. There was a yield of 6·75 tons per acre of Chinese Yams and the Maize gave an excellent crop.

The flock of sheep stood at 91 at the end of the year having increased from 41 at the beginning of the year.

Station Development.

Building construction included :—

Completion of alterations to permanent houses.

Dispensary and houses for Senior Nurse and Assistant Nurse.

Ten Insectaries similar to those previously constructed.

Crown Agents Store to house all non-allocated stores.

Range of buildings including Chemical Store room and office, two stores, two garages and fitters' shop.

Permanent food crop store.

Five villages on Square Mile reconditioned for cacao fermenting and drying.

European Club House.

Two batteries of 18-bin propagators and additional Hardening-off Bins.

Alterations to Chemistry Laboratory by the removal of two walls to form one long room.

Extension to Laboratories consisting of a double-storied wing at each end of the main building, giving a 50 per cent. increase of floor space.

Roads, hedges and drains were put in as follows :—

11·8 miles of roads were constructed.

New Area	...	10·15 miles.
Staff Quarters Area	...	1·20 ,,
Old Station Area ...	...	·45 ,,

Eight bridges and 26 large culverts were constructed over swamps and streams.

Five hundred and sixty yards of *Michelia champaca* hedge were planted on the northern boundry of the Old Station.

All drains in the Old Station were regraded and grassed and a further series laid down to drain swampy areas previously under bush.

New clearing and planting included :—

Grass planted on 31 acres of the old vegetable garden and contiguous bush clearings.

Twenty acres of cacao cleared, and planted with varieties of cacao introduced from the West Indies.

Five acres cleared for ornamental nurseries and vegetable garden, and 20 acres for cacao nurseries, all in the newly acquired area.

Meteorology.

Rainfall during the 1945 calendar year was five inches above the eight year mean but the " build up " of soil moisture after the dry period in the latter half of 1944 was slow and growth of cacao was not as vigorous as desirable.

Humidity during the critical period August-November was higher than usual and " black pod," following severe *Helopeltis* damage to the young pods, caused heavy losses.

Towards the end of the year it appeared that reserves of moisture in the soil had been made good, but the months of January, February and March, 1946 were exceptionally dry and conditions approaching drought prevailed.

Meteorological data are recorded in Appendix I.

X. COURSES OF INSTRUCTION.

An agronomist of the Institute has devoted much time to explaining the work in progress to numerous senior Government officials and to

others interested in cacao problems. In addition to this, 16 courses of instruction have been given to parties of farmers and chiefs at the request of and in co-operation with the Department of Agriculture.

The first part of the course consists of a talk on the occurrence and symptoms of capsid attack and swollen-shoot disease, on the recognition of the difference between these and on methods of control. After discussion the party is shown the symptoms in the field and the method of swollen-shoot control by cutting out. In this respect the process of removing diseased trees in the new Square Mile acquisition has provided a valuable demonstration. The party is then shown successful cacao re-establishment on Tafo Station itself and at Akwadum. For comparison, a farm is visited where diseased trees were left prior to re-establishment, and the spread of swollen-shoot into the young cacao is noted.

O. J. VOELCKER,

Director of Cacao Research.

APPENDIX 1.

METEOROLOGICAL DATA.

FIGURES FOR 1945, COMPARED WITH EIGHT YEAR MEANS.

		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Highest Shade Maximum	8 year mean	90·5	93·0	93·1	93·0	91·9	89·1	86·6	86·3	87·8	89·4	90·0	90·1
„ „ „	1945 ...	91	95	93	93	91	89	88	87	90	89	90	90
Lowest Shade Maximum	8 year mean...	60·1	61·6	66·4	66·6	67·3	66·6	66·5	65·0	67·0	66·9	65·5	62·4
„ „ „	1945 ...	61	58	65	66	68	68	67	64	67	67	65	54
Mean Relative Humidity (9 a.m. G.M.T.)	8 year mean	86·6	83·9	80·7	81·0	81·4	84·0	85·3	85·1	84·1	82·1	80·7	82·8
Do.	1945 ...	87·6	80·1	79·2	81·3	78·6	82·6	58·7	84·2	83·8	81·3	80·7	82·9
Mean Relative Humidity (3 p.m. G.M.T.)	8 year mean	53·4	48·9	50·7	53·7	57·0	63·2	64·5	62·0	69·5	68·5	64·8	61·3
Do.	1945 ...	54·0	48·7	57·4	58·6	60·1	62·9	76·9	68·7	69·5	68·3	61·2	59·3
Rainfall in inches	8 year mean	1·77	3·61	4·77	6·30	7·58	7·51	5·31	2·78	5·55	8·70	5·99	2·68
	1945 ...	1·40	3·47	5·17	7·60	3·96	6·34	11·47	2·06	6·47	11·96	5·65	3·32
Number of wet days	8 year mean	4·5	6·5	11·4	11·5	14·4	17·6	13·1	12·4	16·8	17·0	11·6	7·3
Do.	1945 ...	3	8	13	9	13	15	22	13	18	19	12	7

ANNUAL RAINFALL FIGURES—1938–45.

1938	1939	1940	1941	1942	1943	1944	1945	8 year mean.
Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches	Inches
55·33	84·96	56·92	56·39	59·45	69·09	49·12	68·87	63·79

WEST AFRICAN CACAO RESEARCH INSTITUTE—TAFO.

STATEMENT OF POSITION AS AT 31ST MARCH, 1946.

LIABILITIES.

	£ s. d.	£ s. d.
CREDITORS :—		
Gold Coast Government :—		
Amount per last Statement of Position ...	30,000 0 0	
Remittances for year to 31st March, 1946 ...	78,500 0 0	
Amount paid by Gold Coast Government in respect of :—		
Tafo Buildings £18,937 6 1		
Tafo Equipment 1,485 3 1		
Pension Fund 1,750 2 8		
	22,172 11 10	
		130,672 11 10
HONOURABLE DIRECTOR OF AGRICULTURE ACCRA :—		
Amount per last Statement of Position ...		10,200 3 3
COMMISSIONER OF LANDS :—		
Amount per last Statement of Position ...		187 2 3
UNCLAIMED WAGES		1 13 3
		£141,061 10 7

ASSETS.

	£ s. d.	£ s. d.
DEBTORS :—		
Staff Advances		936 18 2
STOCKS :—		
Unallocated Stores and Materials on Hand ...		4,870 17 6
CASH :—		
	£ s. d.	
In Hand—Imprest Account ...	100 0 0	
At Bank on Current Account—Bank of British West Africa Limited—Koforidua	1,709 5 6	
		1,809 5 6
DEFICIT AND SURPLUS ACCOUNT :—		
Balance per last Statement of Position	36,908 12 9	
Add—*Expenditure for year to 31st March*, 1946	98,937 16 6	
	135,846 9 3	
Less *Revenue for year to 31st March*, 1946	2,401 19 10	
		133,444 9 5

(Sgd.) O. J. VOELCKER,
Director of Cacao Research.

£141,061 10 7